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An update on Georges Bank (5Z) herring

by

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Abstract:

Current data on the status of Georges Bank herring are updated. Evidence from Canadian and US fall surveys indicate that the stock is well on its way to recovery. Larval abundance and bottom trawl catch rate indices continue to show annual increases in relative abundance. Positive signs have also been noted in biological indicators such as length composition and age distribution. As well the general distribution of larvae and mature herring appears to be expanding each year.

The question of reappearance verses recolonization is readdressed in light of updated information and future management concerns are identified.

Although there is insufficient data for a plausible estimate of population size, the accumulated evidence for recovery indicates that complete closure of Georges Bank to herring fishing, may not be necessary. Concerns are however expressed about several areas of data deficiencies and the absence of herring on some of their historical spawning grounds. Further information on the geographical extent of spawning is required prior to initiation of a commercial fishery.

Résumé

On actualise les données sur la situation du hareng du banc Georges. Les campagnes d'évaluation automnales réalisées par les États-Unis et par le Canada indiquent que le stock est en bonne voie d'être rétabli. Les indices d'abondance larvaire et de prises au chalut de fond continuent de révéler des accroissements annuels de l'abondance relative. Des résultats encourageants ont également été obtenus en ce qui a trait aux indicateurs biologiques, comme la distribution des longueurs et des âges. De plus, la distribution générale des larves et des harengs adultes semblent s'étendre chaque année.

On pose à nouveau la question de savoir s'il s'agit-là d'une réapparition ou d'une recolonisation, à la lumière d'informations plus récentes, et on cerne divers problèmes de gestion futurs.

Quoique les données soient insuffisantes pour permettre une estimation plausible de la population, l'accumulation de signes de rétablissement du stock donne à penser que la fermeture totale du banc Georges aux pêcheurs de hareng n'est peut être pas nécessaire. On se préoccupe toutefois de l'insuffisance des données dans plusieurs domaines et de l'absence de hareng dans certaines de ses frayères traditionnelles. Il est nécessaire d'obtenir plus de renseignements sur l'etendue de la zone de frai avant d'autoriser une pêche commerciale.

Introduction:

Commercial harvesting of Atlantic herring on Georges Bank began in 1961 and continued until 1977 when the fishery collapsed. During this 18 year period 14 countries reported landings from the bank; the largest catches being made by the USSR, Poland, GDR and FGR (Anthony and Waring, 1980). Details of the fishery's development, activities by foreign fleets and the crash are summarized in Anthony and Waring (1980) and Stephenson et. al. (1987).

Landings during the late 1960's and early 1970's exceeded 200,000 metric tonnes annually and peaked in 1968 at 374,000 mt.(Fogarty et. al.,1989). Unfortunately, coincident with the high level of exploitation were several years of poor recruitment resulting in a dramatic decline in reported landings (Anthony and Waring, 1980; Grosslien, 1987). By 1977 only 2000 mt. of herring were landed. What was once the largest herring fishery on the Western Atlantic coast was "economically extinct" by 1978. The bank has remained closed to herring fishing ever since. No commercial herring fishery has operated on the bank since 1978.

Several papers have reviewed the available information on the reappearance of herring on Georges Bank. Each year more and more evidence is accumulated to suggest that the stock is recovering and expanding. Unfortunately, insufficient data are available to quantify the increase. Stephenson et.al. (1987; 1990) provide a chronological summary of the events leading up to this review.

This report summarizes the current information available to assess the status of Georges Bank herring. Because it is based on limited, and in some cases incomparable, data being collected by Canadian and US research surveys no attempt has been made to estimate abundance with respect to numbers or weight. The information presented is discussed in a relative sense and is used solely as an indicator of trend in what appears to be a rebuilding of Georges Bank herring stock.

Data Sources:

This report examines fall surveys; which are most relevant to the spawning period. Data sets analyzed to assess the recovery of Georges Bank herring included Canadian fall bottom trawl survey (1986), US fall bottom trawl surveys (1963-90), and the Canadian fall larval/adult herring surveys (1987-1989). Detailed US larval herring survey data were not available at the time this report was being prepared but published summaries of larval data from US surveys were used for comparison. Information from the spring surveys will be examined at a later time.

Differences in sampling objectives, approaches and gear type make direct comparison of the juvenile and adult data invalid. While both the Canadian and U.S. bottom trawl surveys use a stratified random sampling design, adult/juvenile herring collected during the Canadian larval surveys were opportunistic in that tows were made in areas where herring had traditionally occurred. Length frequency data from Canadian and U.S. groundfish cruises are fork lengths measured in 1cm intervals while those from herring cruises are total length measured in 0.5 cm intervals. To over-come the difference, all measurements from the groundfish surveys were converted to total length using the following formula (J. Hunt, Pers Comm.,1991) and rounded-off to the nearest 1cm interval):

$$\text{Total Length (mm)} = 9.56 + 1.09 \times \text{Fork Length (mm)}$$

Whenever possible data from all sources were pooled. Information presented on length frequency and distribution of adult/juvenile herring during the fall represents the Canadian and U.S. catch data combined.

To assist in understanding changes occurring with the Georges Bank herring stock, comparison is made with the two nearby areas which some (Smith and Morse, 1990) believe have contributed to the bank's recovery; Massachusetts Bay and Nantucket Shoals. For this report Georges Bank is demarcated as NAFO sub-division 5Zh, 5Zj, 5Zm and 5Zn, Nantucket Shoals as 5Zd and 5Zg, and Massachusetts Bay as 5Ye (Figure 1).

Distribution:

Since 1982 there has been a marked increase in the geographical range and number of herring caught by Canadian and U.S. research vessels during fall surveys. Figures 2 through 10 display the sampling locations and number of herring greater than 20cm captured between 1982 and 1990 from both data sets combined (Canadian survey data covers only the period from 1986 to 1990, Figures 11-14). Assuming herring greater than 20cm are three years old or older, and potentially reproductively active at the time of sampling, it would not be unrealistic to infer that spawning occurred in the vicinity of capture.

Between 1982 and 1985 very few adult herring were caught on Georges Bank, Nantucket Shoals or in Massachusetts Bay by fall groundfish surveys; maximum catch/tow was 5, 19 and 421 (single catch represented 97% of the total for the year), in 1982, 1984 and 1985 respectively. Table 1 summarizes the catch data (Canada/US combined) for each area. Mean values of the catch/set and catch/set with herring are presented to illustrate that both measures of catch demonstrate the same annual trends. It is also important to note that with the exception of 1984 adult herring have been collected on Georges Bank during the fall (ie. spawning

season) since 1982. No herring were collected during the fall research surveys on Georges Bank between 1979 and 1981.

In 1986 the occurrence of adult herring in bottom trawl sets increased dramatically on both Georges Bank and Nantucket Shoals (Table 1). Associated with this increase was a large decline of the catch/set in Massachusetts Bay when compared with the previous two years. From 1986 to 1990 the area of occurrence widened and catch/set generally increased (1989 the exception) with maximum values occurring in 1990 for both Nantucket Shoals and Georges Bank compared with 1989 for Massachusetts Bay (Tables 1 & 2) (Figures 6-10). Each year the distribution on Georges Bank appears to have expanded. The majority of herring collected on the bank were adults (Table 2 & 3).

During the fall adult herring tend to concentrate along the northern reach of the bank (ie. just north of Cultivator and Georges Shoals, Fig. 1) in an area considered to be their historical spawning grounds. Few herring were caught in the central or southern areas of the bank (Figures 2 - 10). Between 1986 and 1988 the catch and distribution of adult herring on the Northeastern tip of Georges Bank increased and expanded in parallel with Cultivator and Georges shoals. Observed decreases on the northeastern tip in 1989 and 1990 on the Northeastern tip were associated with a general decline in herring catches in 1989 (Georges Bank and Nantucket Shoals) and limited coverage in 1990.

Length Frequency:

Length frequency data of herring in 1 cm intervals are summarized for Georges Bank, Nantucket Shoals and Massachusetts Bay from 1983 to 1990 in Figures 15 through 23. During the early years of the recovery (1983-1984) it is interesting to note that even with very few fish, the modes for all three areas are almost identical. From 1985 onward differences in peak frequencies and ranges begin to appear implying differences in age composition between areas. In general catches in Massachusetts Bay are dominated by larger, and assumed older (no age data available), herring when compared with Nantucket Shoals and Georges Bank. Since 1988 fall catches on Georges Bank have been dominated by smaller (e.g. 1986 mean of 32.8 versus 27.7), presumably younger, herring annually. The size distribution of Nantucket Shoals herring in most years lies between those of Massachusetts Bay and Georges Bank. Unfortunately, at the time of preparation of this report information on the age distribution of herring collected by U.S. research surveys was unavailable. The data presented represents only those fish collected during the Canadian fall surveys from 1986 to 1990.

Age:

In the fall of 1986 the first catches of reproductively active herring were taken by both Canadian and U.S. research vessels (Stephenson and Power, 1989: Stephenson et al. 1987). The 1986 Canadian survey catch was dominated (90%) by 3 year old herring (1983 year-class) indicating successful reproduction in 1983. Since 1986 catches of 3 year old herring on Georges Bank have comprised 40-50% with the exception of 1988 when the samples contained predominately 4 year old fish from the 1984 year-class (Figure 23). This dramatic decline in relative abundance of the 1985 year-class would suggest low spawning stock biomass and/or poor reproductive success during 1985.

The relative strength of the 1983 and 1984 year-classes is illustrated in Figure 23 with the 1984 year-class prevalent in catches until 1990 (age 6). The continued strong representation of 3 year olds in samples during most of the study period (1986-1990) and the broadening of ages in catches since 1986 provides further evidence to support of the recovery of Georges bank herring stock.

Spawning:

The occurrence of reproductively active adult herring in catches (Table 3) on the bank during the fall of 1986 indicates spawning. Successful spawning on Georges Bank has been demonstrated by the presence of small larvae (< 10mm) in ichthyoplankton samples collected by Canadian research surveys since 1987. Figures 24 through 27 summarize the distribution and number of herring larvae per $10m^2$ in relation to all sampling stations from 1987 to 1990.

The Canadian herring survey changed sampling procedure in 1988. In 1987 a series of line transects, 30 min apart, with stations located at 20 min intervals in the northern portion of the bank and 30 min intervals in the southern portion was used to select sampling sites. In 1988 a grid system of eighteen 20 min by 20 min boxes was established for Georges Bank. Within each box a minimum of 4 randomly selected station were identified each year and sampled for herring (Stephenson and Power, 1990). Unfortunately, although the grid system covers most of the historical spawning areas, it does not provide complete coverage of the bank (Figure 28). Table 4 summarizes the larval data collected by each cruise.

Figures (24-27) show that the majority of larvae of all sizes (5-21mm) appear to be concentrated along the northern reach of the bank in the vicinity of Cultivator and Georges Shoals. Furthermore, the figures suggest a broadening of distribution during the study period with the exception of 1989 when larvae

tended to be concentrated in a area just northeast of Cultivator Shoals. Detailed examination of the larval data by number caught and size (mm) revealed that there are three areas where larvae of all sizes were found: One, the area just west and southwest of Cultivator Shoals; two, between Cultivator and Georges Shoals to the northern edge of the bank; and three, northeast of Georges Shoals in an area just west of the Canada/US boundary. Larvae found outside these areas tended to be larger (>10mm).

The approximate time of hatching was estimated by back-calculating from length at the time of capture and growth rate. Growth was assumed to be 0.24mm/day (Chenoweth et. al.,1989). Based on this calculation hatching from 1987 to 1990 varied between Julian day 236 to 312 (August 26 to November 8) (Fig. 29). Peak estimated spawning generally occurred during a 2-3 week period between October 3 and October 18 (Julian day 276-291) (Table 4).

Indices:

Two indices were used to evaluate trends in abundance of the Georges Bank herring stock; one the number of herring caught per standard bottom trawl tow (Canada and US fall), and two, the number of larvae estimated per $10m^2$ from Canadian fall larval surveys. These indices have previously been used by ICES for North Sea herring, CAFSAC for 4X herring and by NMFS for the Gulf of Maine herring (Iles et al., 1985; Stephenson, 1991). In the North Sea larval abundance indices have been found useful in successfully tracking a recovering stock (Anon, 1988).

Figures 30-31 summarize the catch/tow of catches with herring from 1965 to 1983 and 1983 to 1990, respectively for the US surveys in Massachuetts Bay (US Area 1), Nantucket Shoals (US Area 2) and Georges Bank (US Area 3) and from 1986 to 1990 for the Canadian surveys on Georges Bank (Can Area 3). The US catch/tow for Nantucket Shoals and Georges Bank (1965-1990) and the five year Canadian catch/tow on Georges Bank (1986-1990) showed similar trends. Exceptions to their general agreement occurred in 1984 when the US bottom trawl survey collected no herring on Georges Bank, and in 1990, when the US catch per tow on Georges Bank declined while the Nantucket Shoals (US) and the Georges Bank (Canadian) increased.

The two anomalies (1984 and 1990) may in part be explained by survey timing. In both 1984 and 1990 the US sampling of Georges Bank was undertaken earlier than in most years. In early October (1-10) 1990 a Canadian acoustic research survey (N143) collected only 10 herring in 31 tows and detected no recognizable acoustic signals on Georges Bank. The 1990 US survey vessel was operating in the same area during part of this period. Three weeks later the 1990 Canadian herring survey (H222) collected more than 1000 adult herring in each of three sets from the same general location, and echoes presumed to be herring were observed on the sounder. This

would imply that an abrupt change in distribution of herring from the previous cruise had occurred and illustrates the sensitivity of catches to timing. Incidentally, the absence of spawning herring in the 1984 U.S. bottom trawl survey is inconsistent with the subsequent strong representation by the 1984 yearclass in subsequent Canadian surveys.

In spite of these anomalies there is an overall upward trend in the index in all three areas with highest levels throughout the time series occurring during the last few years. Quantitatively, it is not possible to directly compare the pre and post crash periods with observations of the last 5 years, even though the type of net used by the US (Yankee 36) has not changed since 1963. In 1985, the US changed door type for both their spring and fall cruises. The recently observed increases do however indicate that the stock is continuing to rebuild with annual improvement, but the level the stock has reached in relation to the past can't be determined from these data.

The annual mean number of larvae per $10m^2$ on Georges Bank from published US summaries (Smith and Morse 1990) and similar calculations from the 1987-1990 Canadian herring survey (Figure 33) indicate larval production levels consistent with those of the early to mid-70's. Unfortunately, Canadian data are available only from 1987 onward. Here the trend is a peak in 1987 decreasing slightly in 1988 and 1989 with an upswing again in 1990. During the two years when data are available from both data sets a difference in trends is noted although the levels are in the same order of magnitude.

Resurgence vs Recolonization:

Critical to the assessment and management of this apparently expanding stock is an understanding of the mechanism(s) which have contributed to the species reappearance. If Georges Bank herring represent a discrete stock, with lean and peak years dependent upon spawning stock biomass and conditions conducive to increase larval survival for subsequent recruitment, then future assessment will only have to contend with the stock as an independent unit. Alternatively, if it is discovered that the reappearance of herring on the bank resulted from external input then assessment and management must consider not only what is occurring on Georges Bank, but the surrounding area as well. This would also have implication concerning the generally accepted "stock concept"

In the latter event consideration would have to be given to the significance of external contribution at various levels of stock abundance. For example, the reappearance of herring on Georges Bank may have relied upon outside input, from the expansion of spawning range of nearby stocks during the rebuilding process, yet once established may be self-perpetuating. Questions such as

these as well as the contribution from Georges to other fisheries must be addressed before the stock can be properly managed.

Two differing points of view concerning the reappearance of herring on Georges Bank have been put forth in the literature. One postulates resurgence, the other recolonization from adjacent stocks. Stephenson and Kornfield (1990) argue that because of differences in age composition, electromorph frequencies, and the recovery lag time with respect to adjacent populations, there is strong evidence to support the hypothesis of resurgence. Paratheoretically, Smith and Morse (1990) in their analysis of 18 years of larval survey data postulate that larval transport and the expansion of spawning range from Massachusetts Bay to Nantucket Shoals and finally to Georges Bank suggests recolonization rather than resurgence.

Both hypotheses warrant consideration, however neither is without interpretational bias. Stephenson and Kornfield's (1990) argument of differences in age composition between Georges Bank and Jeffery's Ledge for 140 and 30 fish respectively appears rather weak. Similarly, significantly different and uniqueness of isoenzyme electromorph frequencies in a few herring is unusual, but it is not conclusive evidence for a discrete population. Lag time to the observed rebuilding could also be interpreted as supporting recolonization by means of an expanding population.

At first glance Smith and Morse's (1990) progression of larvae from Massachusetts Bay via Nantucket Shoals to Georges Bank appears to be a logical interpretation of the data presented. Yet upon closer examination and incorporation of Canadian Survey data it is evident that several exceptions are hidden in the generalized pattern. The presentation of data in 6 and 5 year summaries (Smith and Morse, fig. 3 & 4) does not permit the evaluation of the year by year transition. From their figure 3 it is obvious that sometime between 1977 and 1982, 4-7mm larvae which would imply spawning, were observed in the traditional area of herring spawning on Georges Bank. If these larvae were present on Georges Bank in 1977 it would result in a different interpretation then it would if the larvae occurred in 1983. The latter year incidentally corresponds to the year-class which first (1986) appeared in future survey catches. Examination of the year to year changes in distribution may help to better evaluate the uncertainties.

As well figure 4 of Smith and Morse, 1990 suggests that no 4-7mm larvae were observed on Georges Bank between 1983 and 1987. Data collected during a Canadian research cruise in November of 1987 shows a large concentration of all size ranges of herring larvae (11% of the 4548 larvae were < 8mm) in the areas where spawning was known to occur historically. This indicates that spawning did occur on Georges Bank in 1987. Finally the contouring methodology used for presentation by these authors may

be somewhat misleading in itself. Comparison of figure 1(c) and 5(c) demonstrates the extent of extrapolation by their methodology in that the distribution of larval concentration from a point may continue to be plotted 46 km from the sampling station. Thus caution is warranted when interpreting these results.

The information presented in this review provides additional support in part for the resurgence hypothesis in that significant ($P < 0.05$) annual differences in mean length and mean catch/tow occurred between Massachusetts Bay and Georges Bank. However, there appears to be consistent similarity between Nantucket Shoals and Georges Bank. This implies either that factors affecting spawning and subsequent recruitment are similar or that given the location of Nantucket Shoals, the herring stock is a westerly extension of Georges Bank. More research is needed to investigate the relationship.

Prognosis:

Present data provide further evidence to support the continued recovery of Georges Bank herring. Both larval and bottom trawl survey indices indicate substantial increases since the lean period of the early nineteen eighties. Some concern, however, has been expressed about the comparability of indices originating from different sources. The presence of small larvae (<10 mm) combined with the occurrence of reproductively active herring confirm successful spawning on the bank each year since at least 1987. Spawning appears to be limited to areas in the vicinity of Cultivator and Georges Shoals and to the western portion of the northern edge. Currently there is no evidence of herring spawning in traditional areas on the Canadian side of Georges Bank, although data for this area are limited. The increase in the number of year classes since 1986 and the strong annual representation of 3 year olds in 4 of the 5 years for which data are available are also positive signs.

Given the continued evidence of recovery of this stock complete closure of Georges Bank to the commercial harvesting of herring can no longer be recommended. However, the currently available data are insufficient to estimate potential yield under TAC management. To date serious concerns have been expressed about the lack of an estimate of population size and the undocumented distribution of these fish during much of the year. There is also concern about the incomplete occupation of the traditional eastern spawning grounds.

While it is noted that management will be under increasing presure to open the fishery, the need for Canada/US cooperation and agreement in scientific and management initiatives for this stock is reiterated.

It is also recognized that the annual research survey provides only limited data. Further information on the geographic extent of spawning is required prior to initiation of a commercial fishery. A survey involving commercial vessels could help in this respect. During 1991/91 discussions with industry and US scientists could be carried out to further define the nature of such a survey.

Recommendations

In light of new information it is recommended:

1) The Canadian larval survey should be expanded to include the eastern portion of the bank.

2) The comparability of pre and post crash indices be evaluated, particularly the impact of US gear change and larval survey design.

3) Consideration should be given to small exploratory ("Scientific") fishery involving commercial vessels.

4) Research be undertaken to document attributes (such as movement, growth, mortality and fecundity) of this stock.

Literature cited

Anon. (ICES). 1988. Report of the herring assessment working group for the area south of 62°N. Int. Counc. Explor. Sea C.M. 1988/Assess: H17: 205 p.

Anthony, V. C., and Waring. 1980. The assessment and management of the Georges Bank herring fishery. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 177:72-111.

Chenoweth, S. B., D. A. Libby, R. L. Stephenson and M. J. Power. 1989. Origin and dispersion of larval herring (Clupea harengus) in coastal waters of Eastern Maine and Southwestern New Brunswick. Can. J. Fish. Aquat. sci. 46: 624-632.

Fogarty, M. J., F. P. Almeida, J. Chenoweth and J. S. Idione. 1989. Population dynamics of Atlantic herring in the Gulf of Maine. SAW-9 Working Paper No. 7: 50p.

Grosslien, M. D. 1987. Synopsis of knowledge of the recruitment process for Atlantic herring (Clupea harengus), with special reference to Georges Bank. NAFO Sci. Coun. Studies 11: 91-108.

Iles, T. D., M. J. Power, and R. L. Stephenson 1985. Evaluation of the use of larval survey data to tune herring stock assessments in the Bay of Fundy/Gulf of Maine. Int. Comm. Northwest Atl. Fish. Res. SCR Doc. 85/107:16 p.

Lough, R. G., G. R. Bolz, M. Pennington and M. D. Grosslien. 1985. Larval abundance and mortality of Atlantic herring (Clupea harengus L.) spawned in the Georges Bank and Nantucket Shoals areas, 1971-1978 seasons, in relation to spawning stock size. J. Northw. Atl. Fish. Sci. Vol 6: 21-35.

NOAA. 1990. Report of the eleventh NEFC stock assessment Workshop fall 1990. Northeast Fisheries Center Ref Doc. 90-09: 58-65.

Smith, W. G. and W. W. Morse. 1990. Larval Distribution Patterns: Evidence for the collapse/recolonization of Atlantic herring on Georges Bank. Int. Counc. Expl. Sea ICES C.M. 1990/H:17: 16p.

Stephenson, R. L., D. J. Gordon and M. J. Power. 1987. Herring of the outer Scotian Shelf and Georges Bank: History of the fisheries, recent developments and management considerations. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 87/76: 23p.

Stephenson, R. L., and M. J. Power. 1989. Reappearance of Georges Bank herring: a biological update. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 89/60: 14p.

Stephenson, R. L. and I. Kornfield. 1990. Reappearance of spawning Atlantic herring (Clupea harengus harengus) on Georges Bank: population resurgence not recolonization. Can J. Fish. Aquat. Sci. 47: 1060-1064.

Stephenson, R. L., M. J. Power and D. J. Gordon. 1990. Reappearance of Georges Bank (5Z) herring: a biological update. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 90/54: 38p.

Stephenson, R. L. 1991. Comparison of tuning methods used in herring stock assessments in the Northwest and Northwest Atlantic. Int. Counc. Explor. Sea. C.M. 1991/H:39.

Table 1. Summary of Canada and US fall research cruise data combined for area 1 - Massachusetts Bay, Area 2 - Nantucket Shoals, and Area 3 - Georges Bank, by year. Note Canadian cruises started in 1986; before then the summary is based on US catches only.

Year	Area	Date start	Date finish	Total sets	Sets with herring	% with herring	No. herring	Catch all sets		Catch sets with herring		Length	
								$\bar{x}$	STD	$\bar{x}$	STD	$\bar{x}$	STD
1982	1	11-06	11-08	7	3	43	4	0.57	0.98	2.0	0.0	32.6	0.0
	2	10-12	11-09	40	6	15	10	0.25	0.74	1.67	1.21	31.1	2.02
	3	10-19	11-11	72	3	4	7	0.10	0.61	2.33	2.31	32.9	2.77
1983	1	10-26	11-09	16	7	44	22	1.37	2.15	3.14	2.27	29.2	5.20
	2	10-12	11-09	33	5	15	18	0.55	1.79	3.60	3.43	33.3	3.02
	3	10-09	10-23	95	3	3	4	0.04	0.25	1.33	0.58	30.9	4.74
1984	1	10-11	11-06	9	6	67	145	16.11	27.74	24.17	31.59	33.1	3.49
	2	10-05	11-17	21	4	19	22	1.05	4.13	5.50	9.00	31.7	4.96
	3	10-07	10-25	73	0	0	0	-	-	-	-	-	-
1985	1	11-13	11-15	6	4	67	435	72.5	170.8	108.8	208.2	31.1	2.85
	2	10-18	11-07	28	4	14	16	0.57	1.55	4.0	1.83	31.5	1.87
	3	10-22	10-25	63	2	3	4	0.06	0.40	2.0	1.41	28.5	0.55
1986	1	10-27	11-05	8	3	38	9	1.13	1.64	3.00	1.00	32.8	3.31
	2	10-09	10-28	22	4	18	89	4.05	15.34	22.25	33.26	29.9	2.08
	3	10-09	11-15	103	23	22	241	2.06	6.83	9.21	12.12	27.71	1.51
1987	1	10-08	10-27	8	6	75	438	54.75	118.17	73.0	133.98	27.5	2.85
	2	10-02	10-29	24	10	42	832	34.66	108.43	83.2	159.88	28.9	3.12
	3	10-03	11-10	75	28	61	346	9.89	39.78	26.50	62.30	29.7	2.57
1988	1	10-26	10-27	11	9	82	85	7.73	8.67	9.44	8.71	38.7	3.03
	2	09-29	10-18	25	7	28	1650	66.00	248.24	235.71	447.02	29.2	2.66
	3	10-07	11-11	81	39	48	2127	22.48	71.17	46.69	97.50	27.3	4.64
1989	1	10-21	10-30	11	10	91	5182	471.09	751.74	518.2	775.10	31.20	2.67
	2	10-07	10-17	19	5	26	280	14.74	42.83	56.00	73.25	30.2	2.40
	3	10-08	11-06	88	46	52	881	10.22	36.99	19.56	49.58	27.9	3.64
1990	1	10-16	10-23	7	4	57	234	33.42	41.41	58.5	38.39	30.8	3.09
	2	09-27	10-16	35	9	26	3044	86.97	326.61	338.22	598.15	27.5	2.32
	3	10-06	11-09	83	27	33	6051	72.90	314.7	224.11	526.47	26.9	2.37

Table 2. Comparison of Canadian and U.S. Georges Bank fall cruise data from 1987-1990. Mean length of all herring collected and those > 20 cm is presented for comparisons.

Year	Country	Date start	Date finish	Total sets	Sets with herring	% with herring	No. herring	Catch all sets		Catch sets with herring		Length all		Length (>20 cm)	
								x	STD	x	STD	x	STD	x	STD
1986	Can.	10-29	11-05	41	12	29.2	83	2.0	5.49	6.9	8.52	27.3	1.46	27.3	1.46
	USA	10-09	10-21	62	11	17.6	129	2.1	7.63	11.7	15.17	28.1	1.47	28.1	1.47
1987	Can.	11-03	11-10	11	5	45.5	396	36.0	59.16	79.2	66.87	26.5	2.50	26.5	2.51
	USA	10-03	10-18	64	17	26.5	346	5.4	34.12	20.4	65.27	29.7	2.34	29.7	2.34
1988	Can.	11-06	11-11	20	14	70.0	1328	66.4	104.69	94.9	114.50	27.4	5.09	29.1	1.83
	USA	10-07	10-18	61	19	31.2	493	8.1	49.31	25.9	87.26	28.0	4.70	29.4	1.96
1989	Can.	11-04	11-06	24	15	62.5	694	29.9	65.04	47.5	77.73	28.2	2.75	28.2	2.75
	USA	10-08	10-25	64	22	34.4	187	2.9	12.09	8.5	19.71	28.8	5.74	28.6	3.20
1990	Can.	11-07	11-09	21	18	85.7	6022	286.8	584.6	334.5	620.7	26.8	2.34	26.8	2.34
	USA	10-06	10-11	62	6	9.6	29	0.5	2.70	4.8	7.96	30.1	2.58	30.1	2.58

TABLE 3. Summary of gonad development stage of herring collected on Georges Bank during October and November. The values 1-8 represent gonad stages of a modified Hjort Scale. Percent of sample is included in brackets.

Year	1	2	3	4	5	6	7	8	Number samples
1986	-	10 (9.3)	1 (0.9)	-	6 (5.6)	30 (2.8)	2 1.9	59 (54.6)	108
1987	1.0 (.2)	181 (45.9)	- -	- -	10 (2.5)	24 (6.1)	14 (3.6)	164 (41.6)	394
1988	23 (7.7)	24 (8.8)	5 (1.7)	3 (1.0)	1 (0.3)	1 (0.3)	13 (4.3)	230 (76.7)	300
1989	- -	24 (19.0)	4 (3.2)	- -	1 0.8	3 2.4	33 (26.2)	61 (48.4)	126
1990	46 (8.8)	115 (22.0)	- -	- -	18 (3.4)	4 (.8)	120 (23.)	218 (41.8)	582

Table 4. Summary of larval herring survey data (1987-1990). The number in brackets under date of sampling are Julian days.

				#/10m²		Length				Estimated Hatching Day (Julian)			
Cruise #	Date of sampling	Number Caught	# of Stations	Mean	STD	(mm) mean	STD	(mm) min.	(mm) max.	Mean	STD	Min.	MAX
H181	23 Oct - 10 Nov (296-314)	4898	47	126.4	371.8	10.38	1.94	5	19	291	7.71	253	312
H195	28 Oct - 7 Nov (301-311)	4075	76	53.9	82.8	13.09	3.05	6	21	274	14.2	238	309
H207	25 Oct - 5 Nov (298-309)	4386	91	53.8	164.1	12.41	1.78	7	21	277	7.34	238	301
H222	31 Oct - 10 Nov (304-314)	5903	79	102.1	169.6	11.64	1.88	7	19	280	8.08	248	299

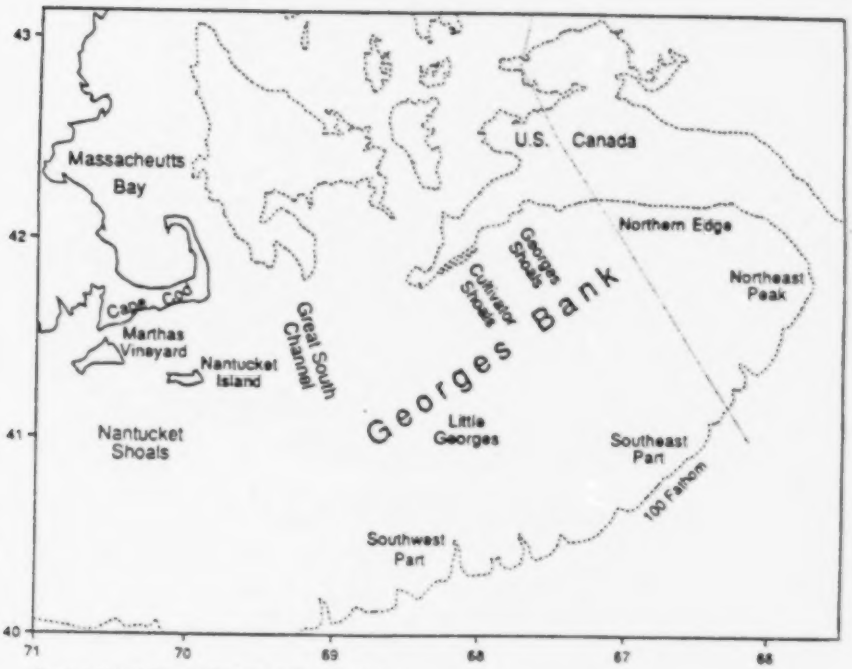

Figure 1. Map of Georges Bank and surrounding area.

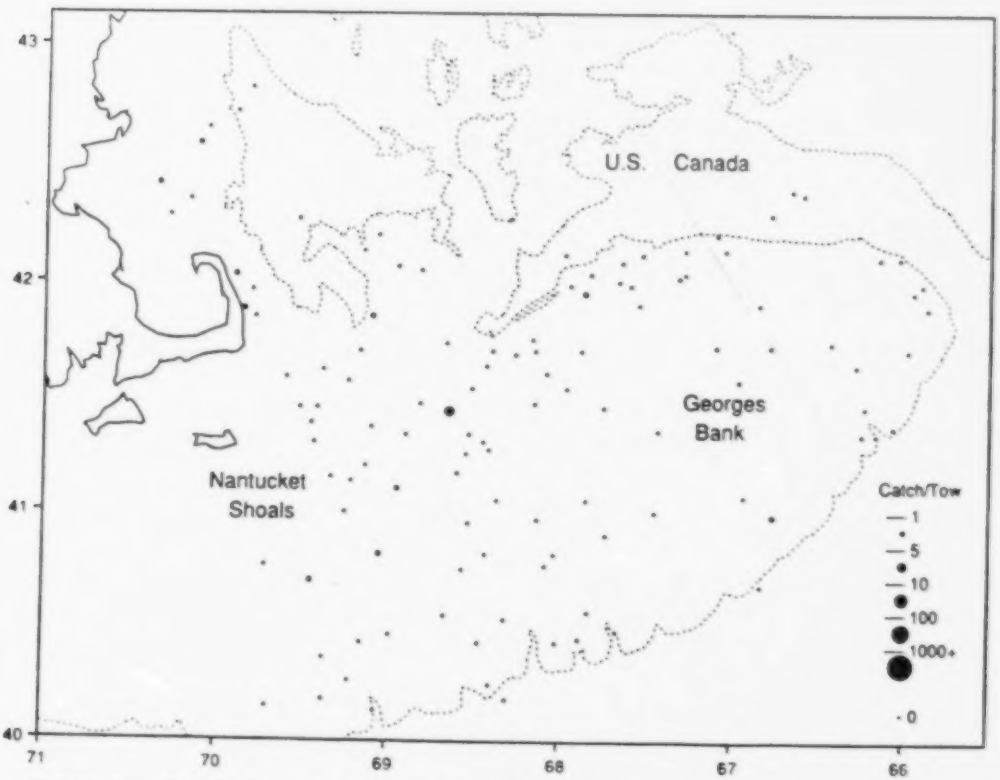

Figure 2. US Fall Bottom Trawl Survey - 1982.

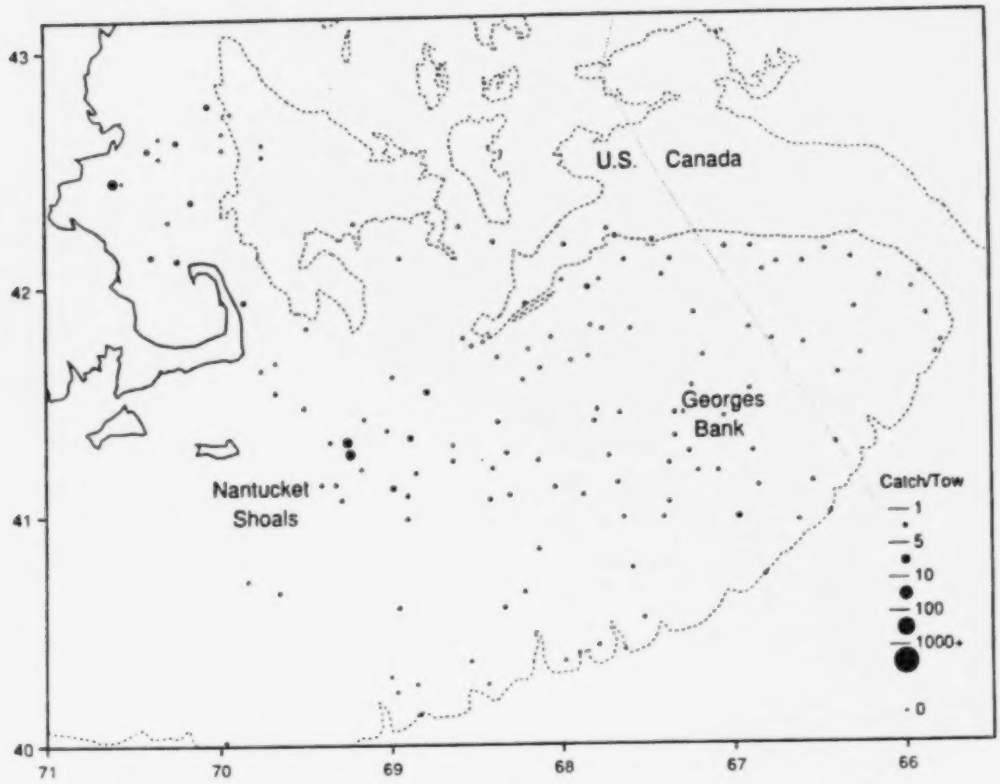

Figure 3. US Fall Bottom Trawl Survey - 1983.

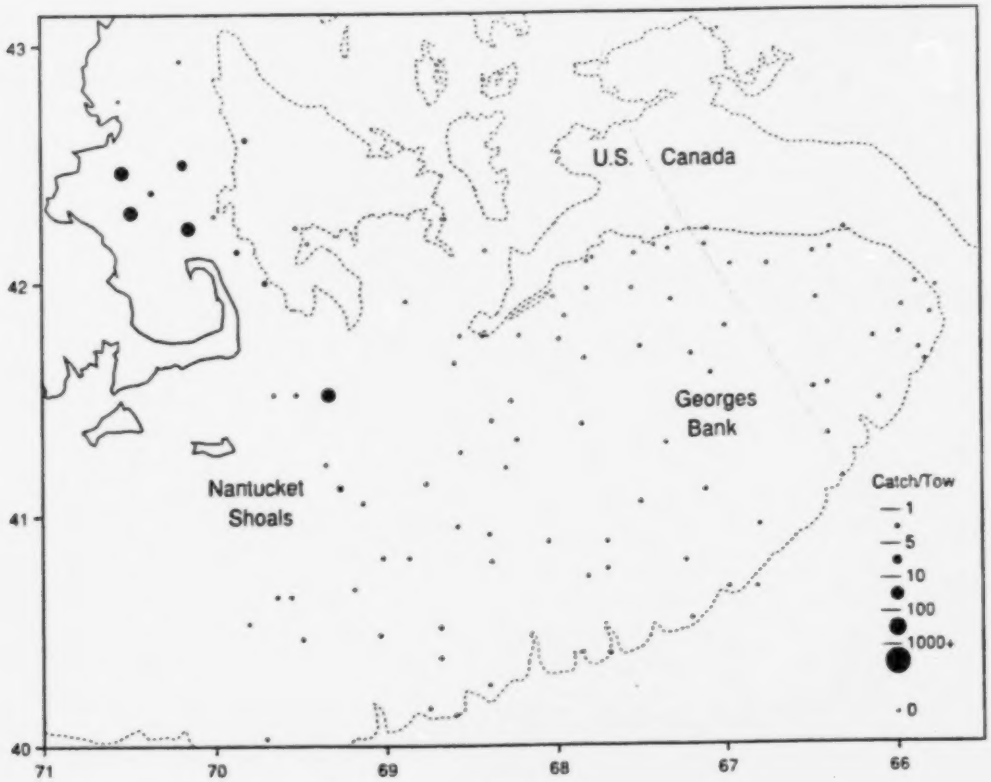

Figure 4. US Fall Bottom Trawl Survey - 1984.

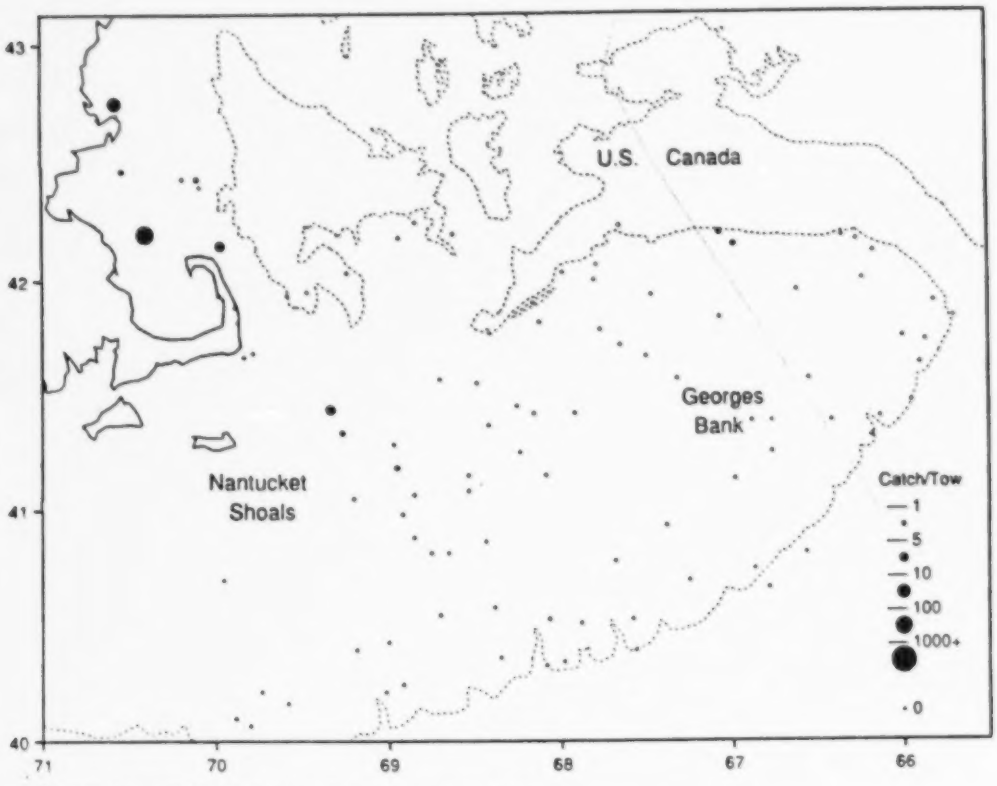

Figure 5. US Fall Bottom Trawl Survey - 1985.

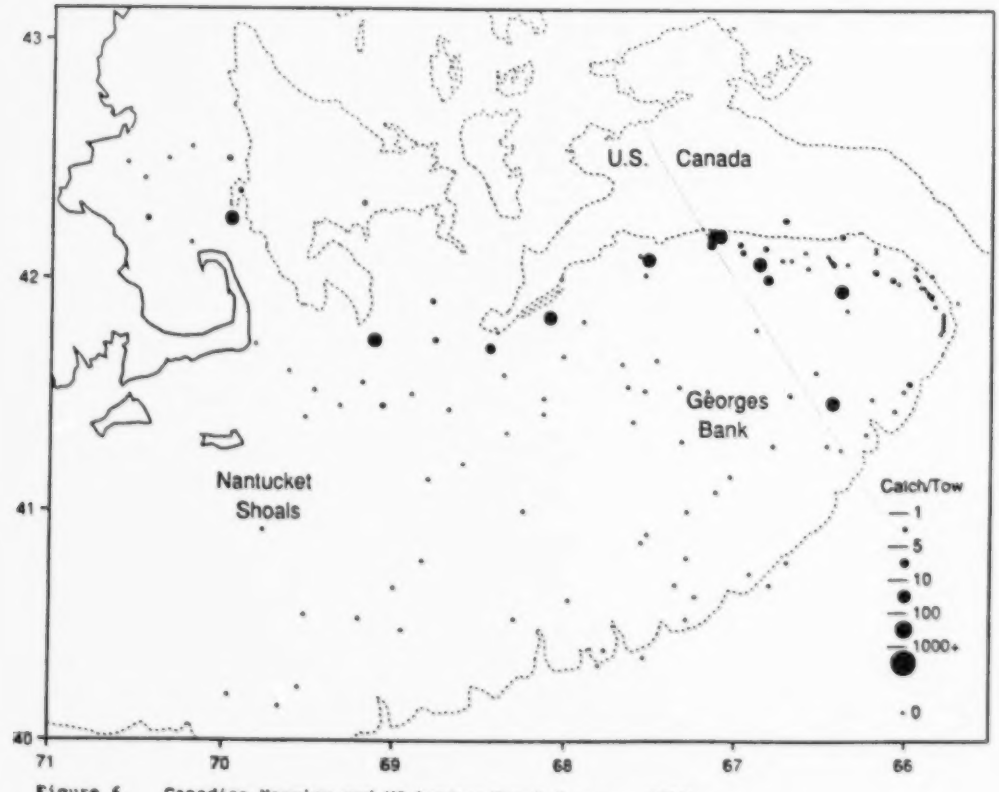

Figure 6. Canadian Herring and US bottom Trawl Survey - 1986.

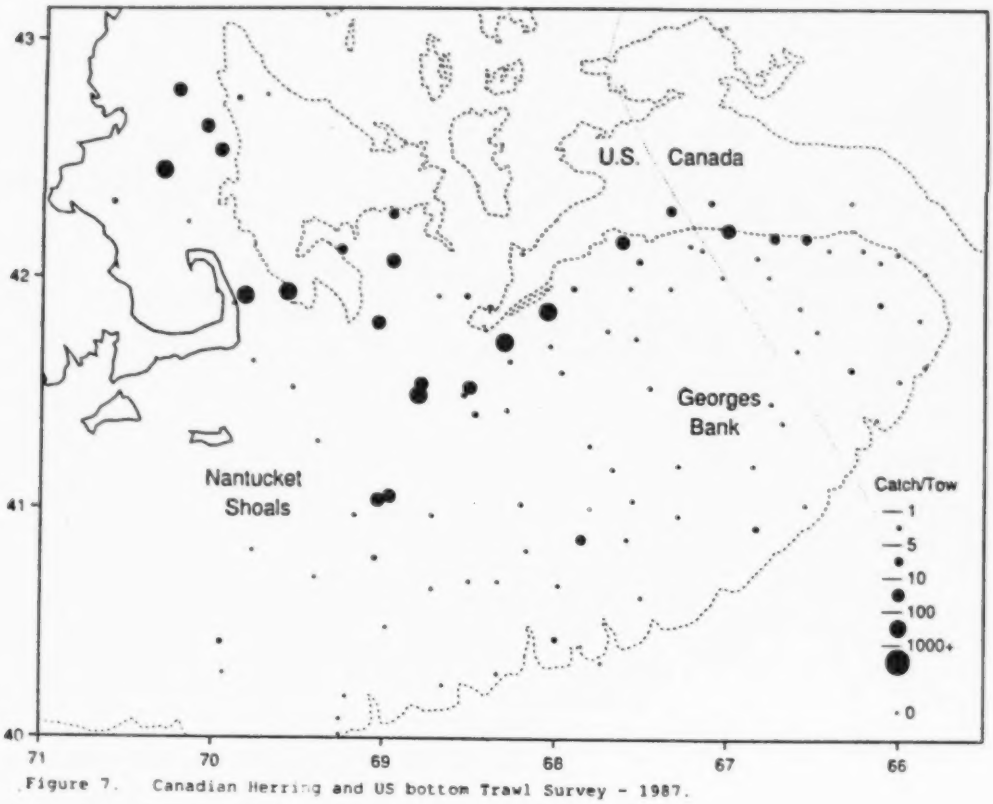

Figure 7. Canadian Herring and US bottom Trawl Survey - 1987.

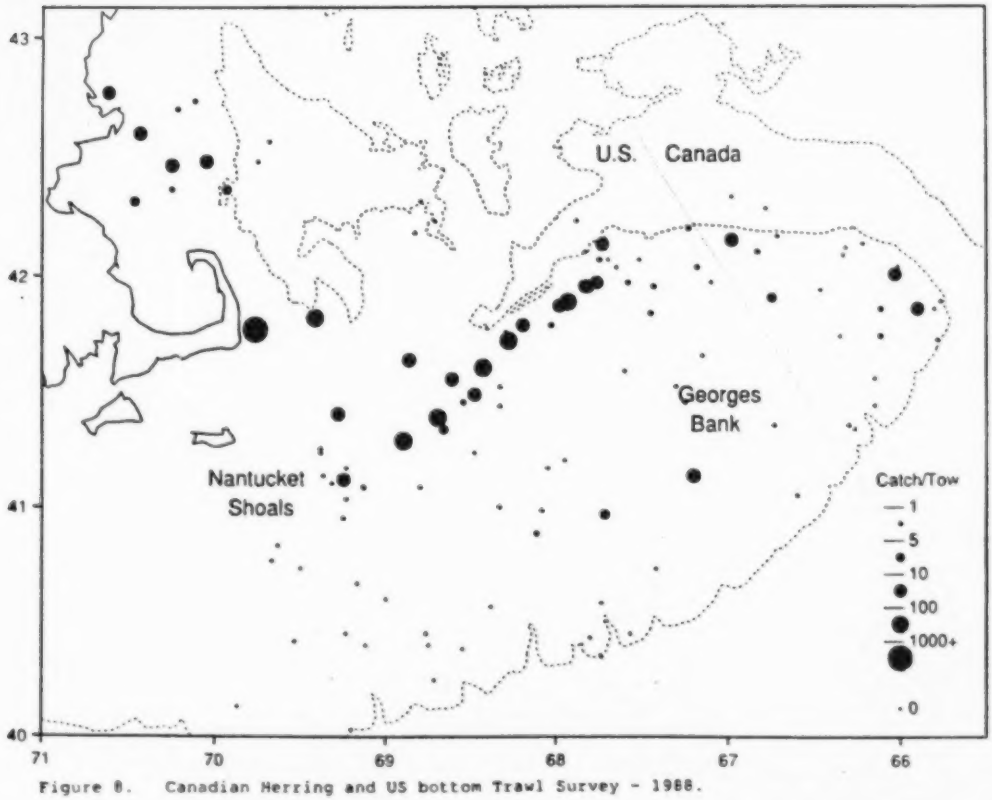

Figure 8. Canadian Herring and US bottom Trawl Survey - 1988.

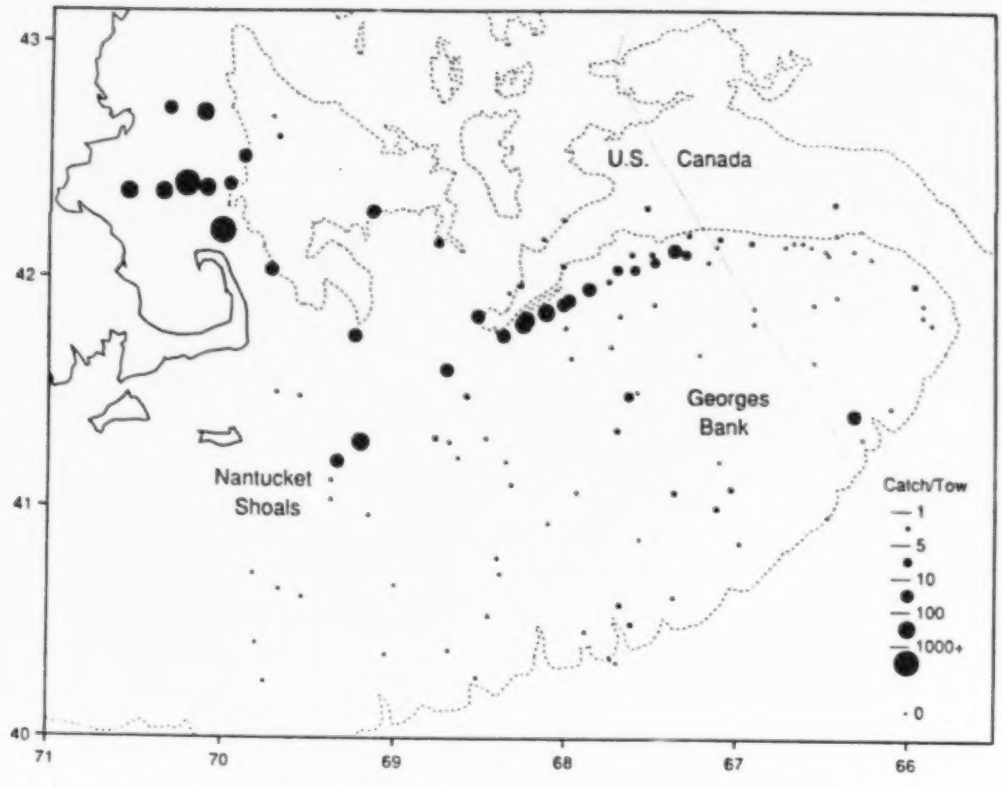

Figure 9. Canadian Herring and US bottom Trawl Survey - 1989.

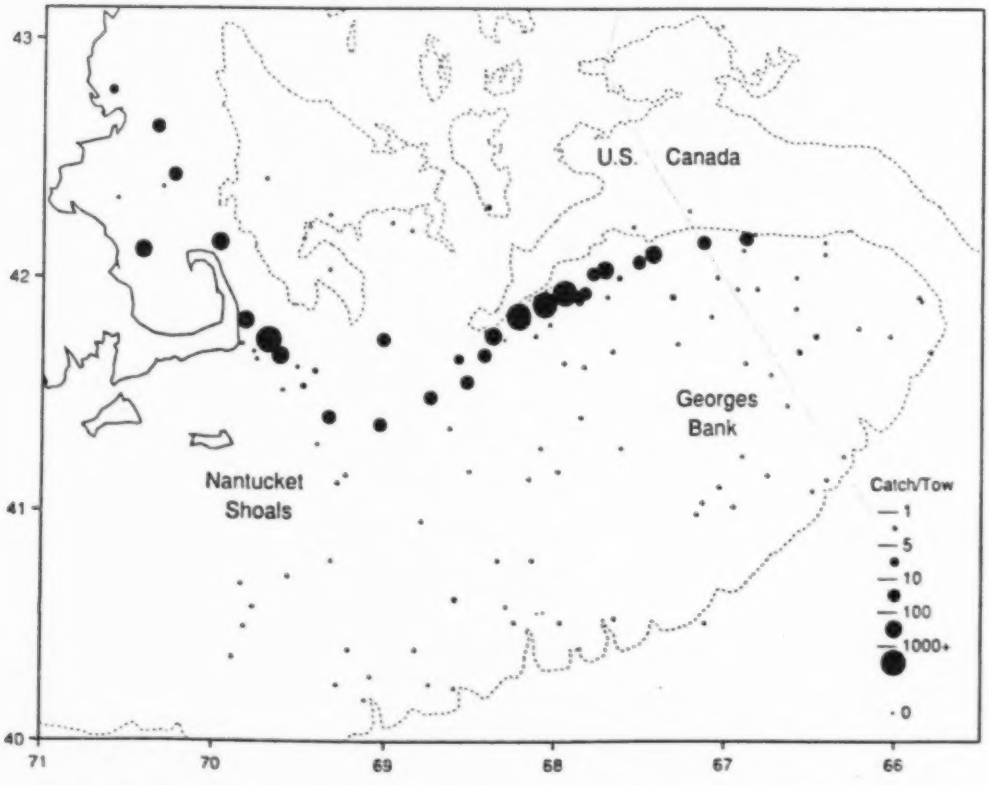

Figure 10. Canadian Herring and US bottom Trawl Survey - 1990.

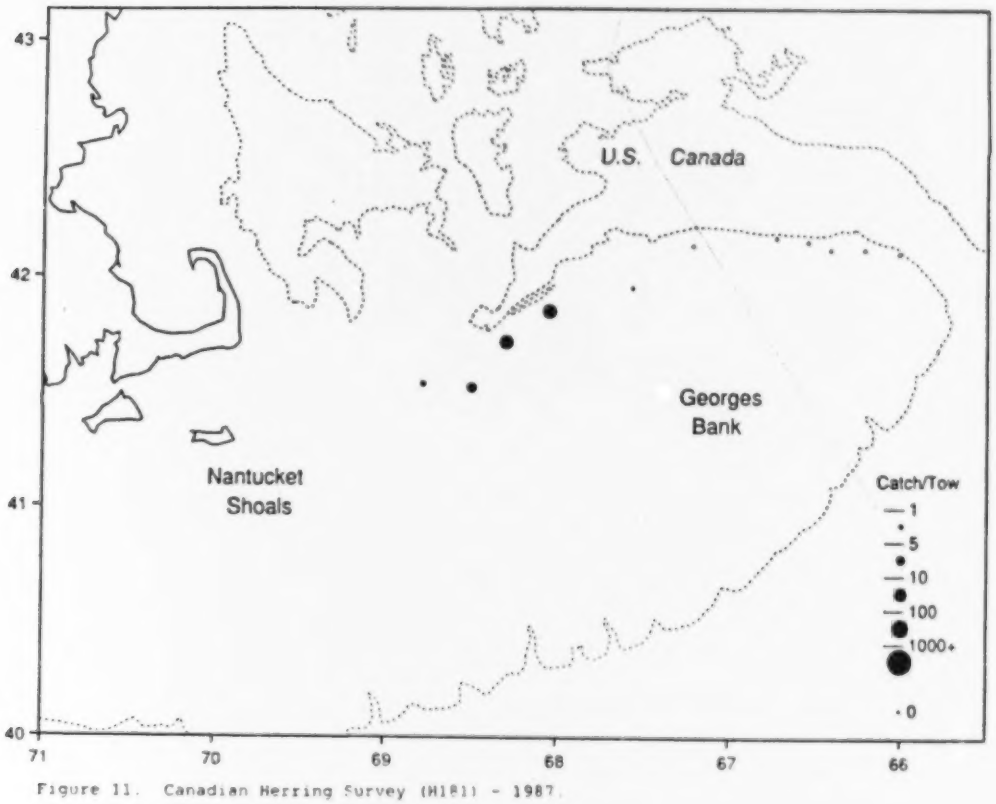

Figure 11. Canadian Herring Survey (H181) - 1987.

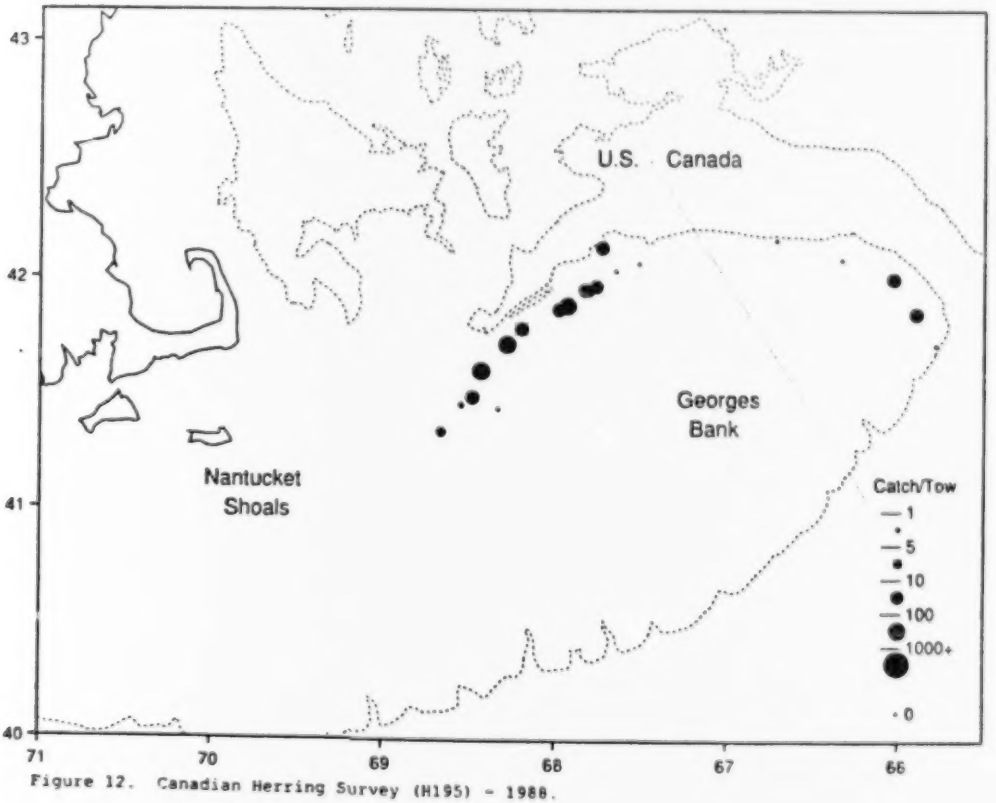

Figure 12. Canadian Herring Survey (H195) - 1988.

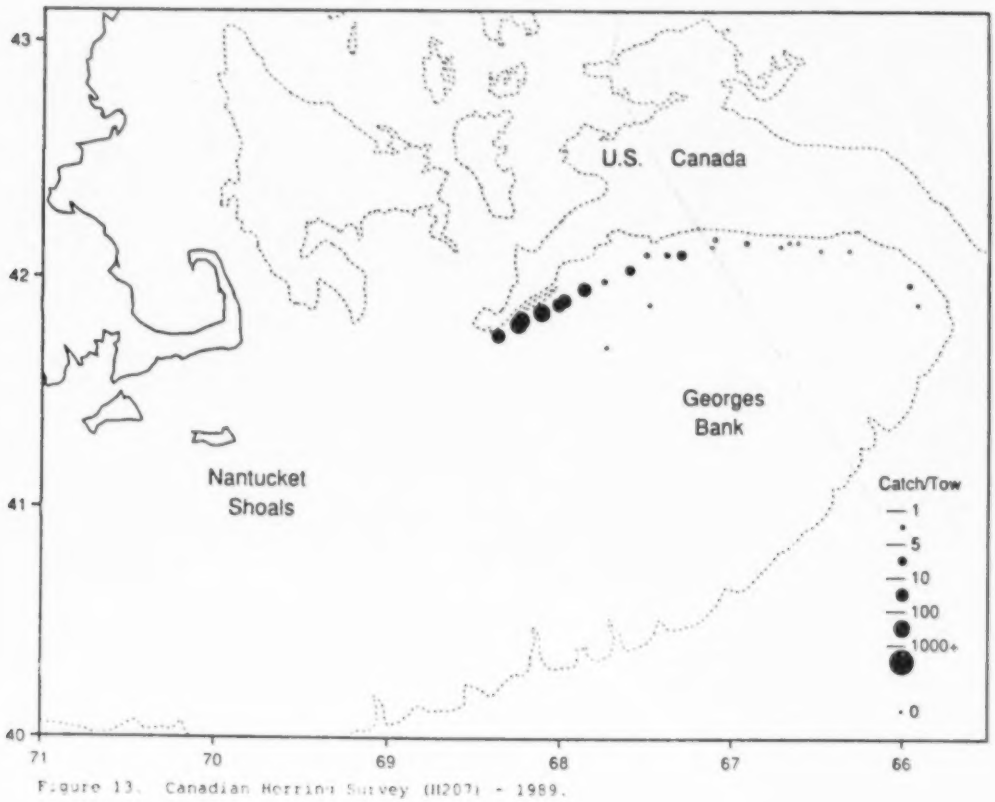

Figure 13. Canadian Herring Survey (H207) - 1989.

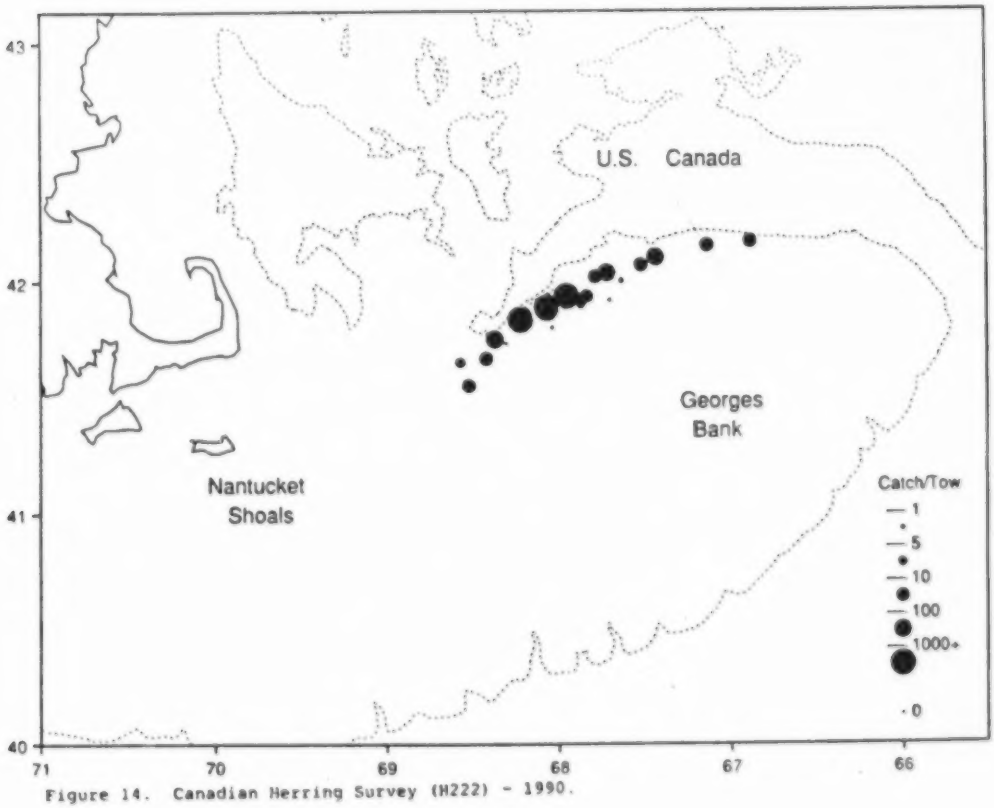

Figure 14. Canadian Herring Survey (H222) - 1990.

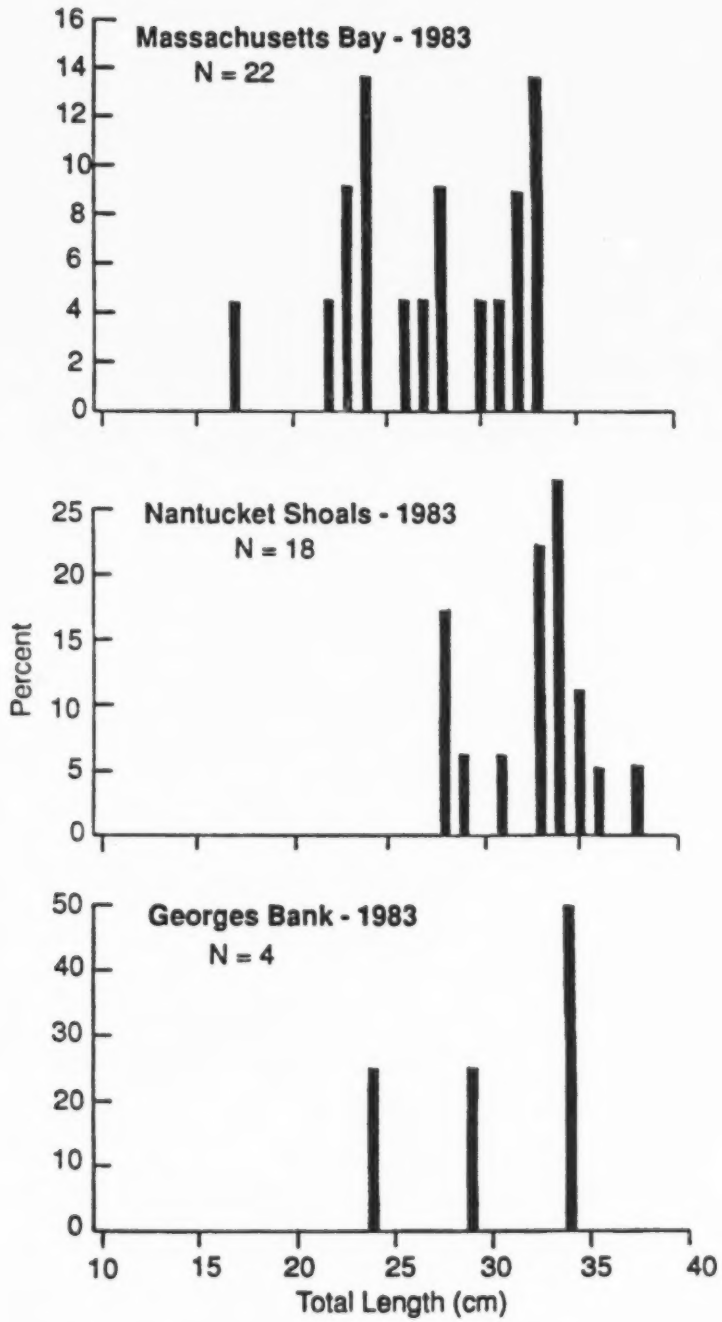

Figure 15. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals and Georges Bank for 1983.

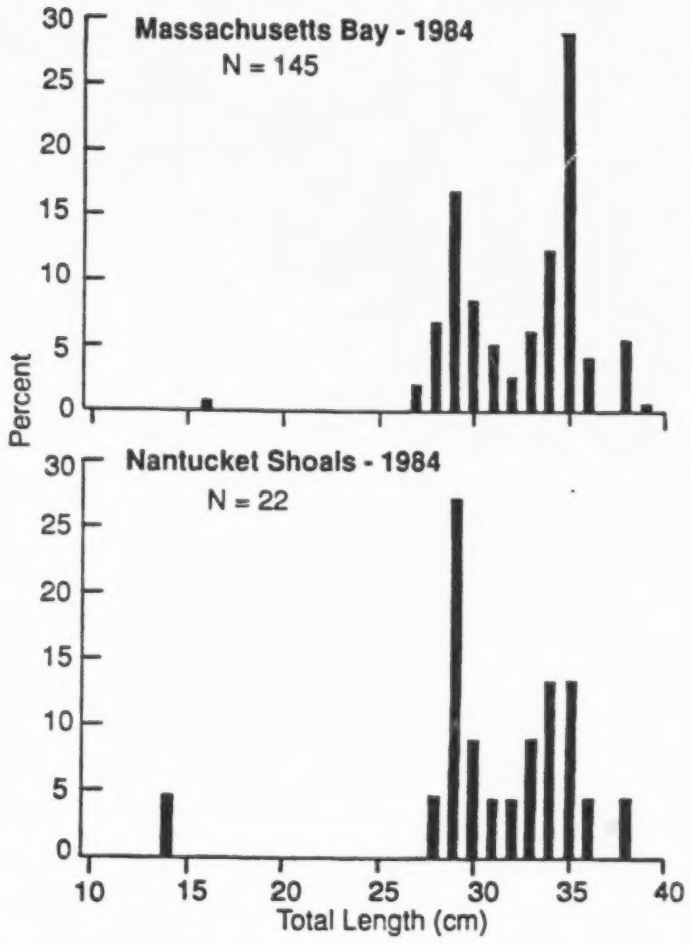

Figure 16. Length-frequency composition of samples collected from Massachusetts Bay and Nantucket Shoals.

Note. No herring were collected from Georges Bank in 1984.

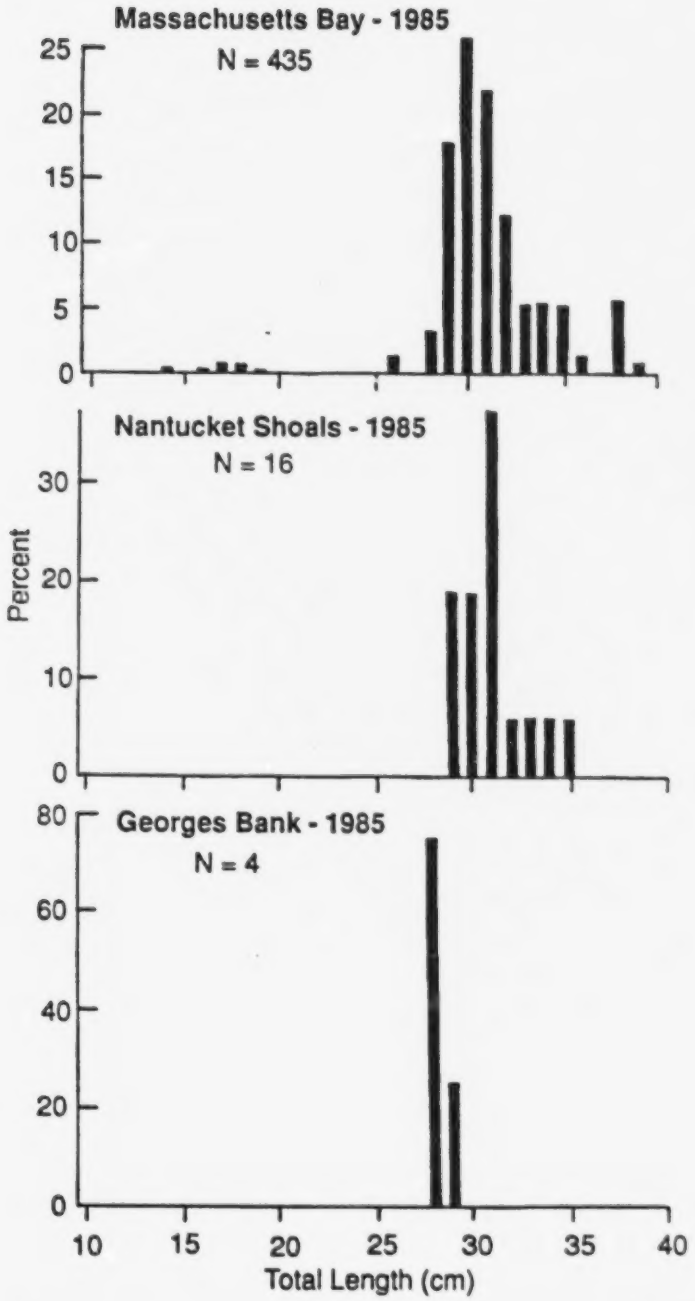

Figure 17. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals and Georges Bank for 1985.

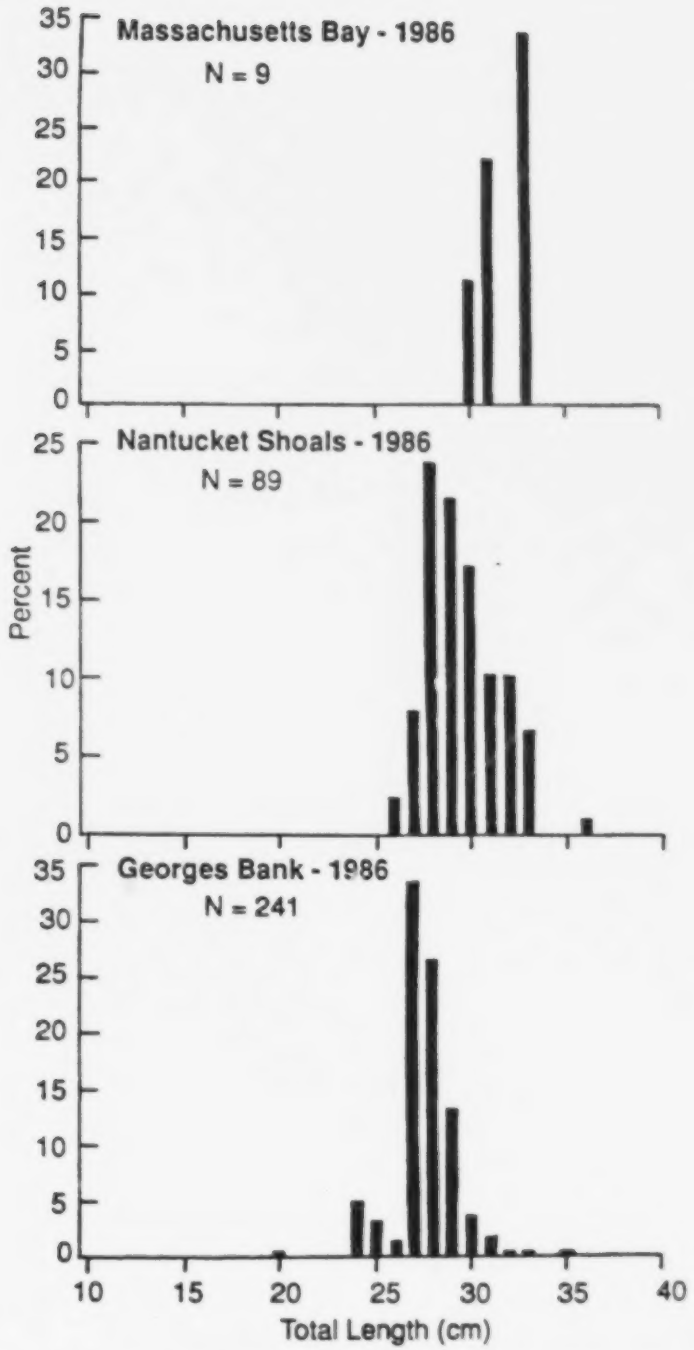

Figure 18. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals and Georges Bank for 1986.

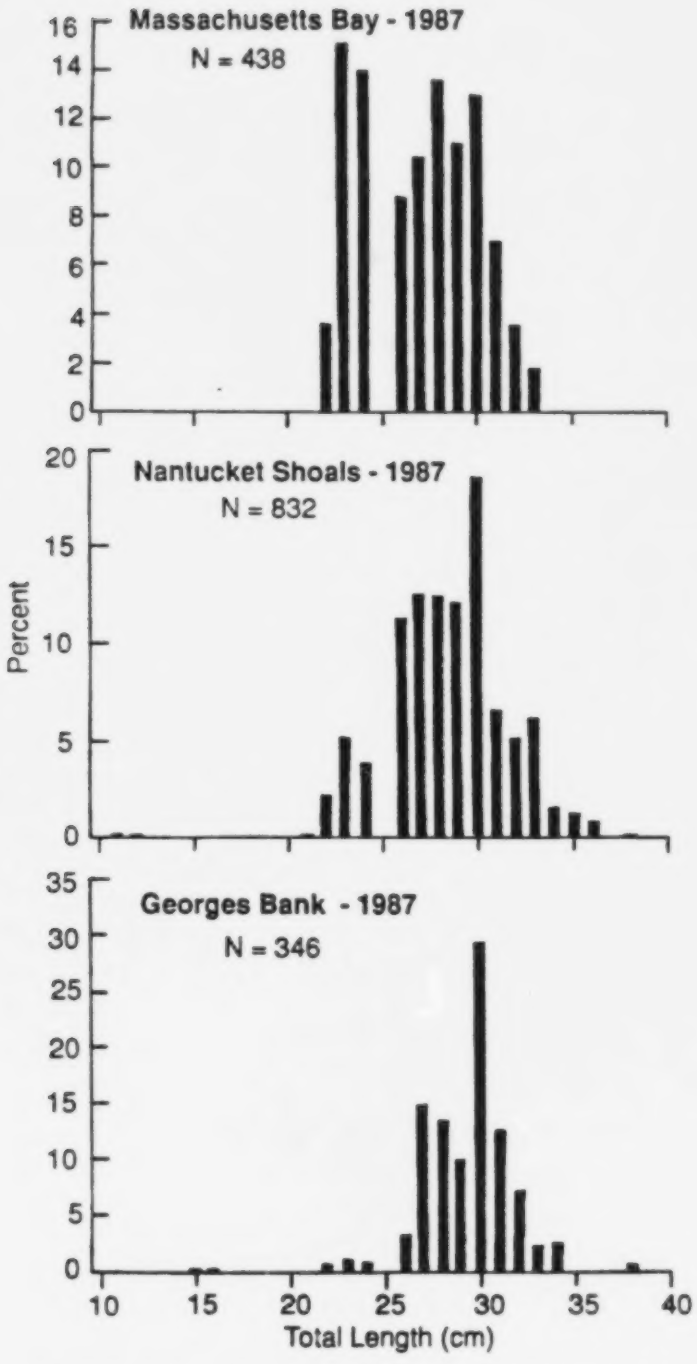

Figure 19. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals and Georges Bank for 1987.

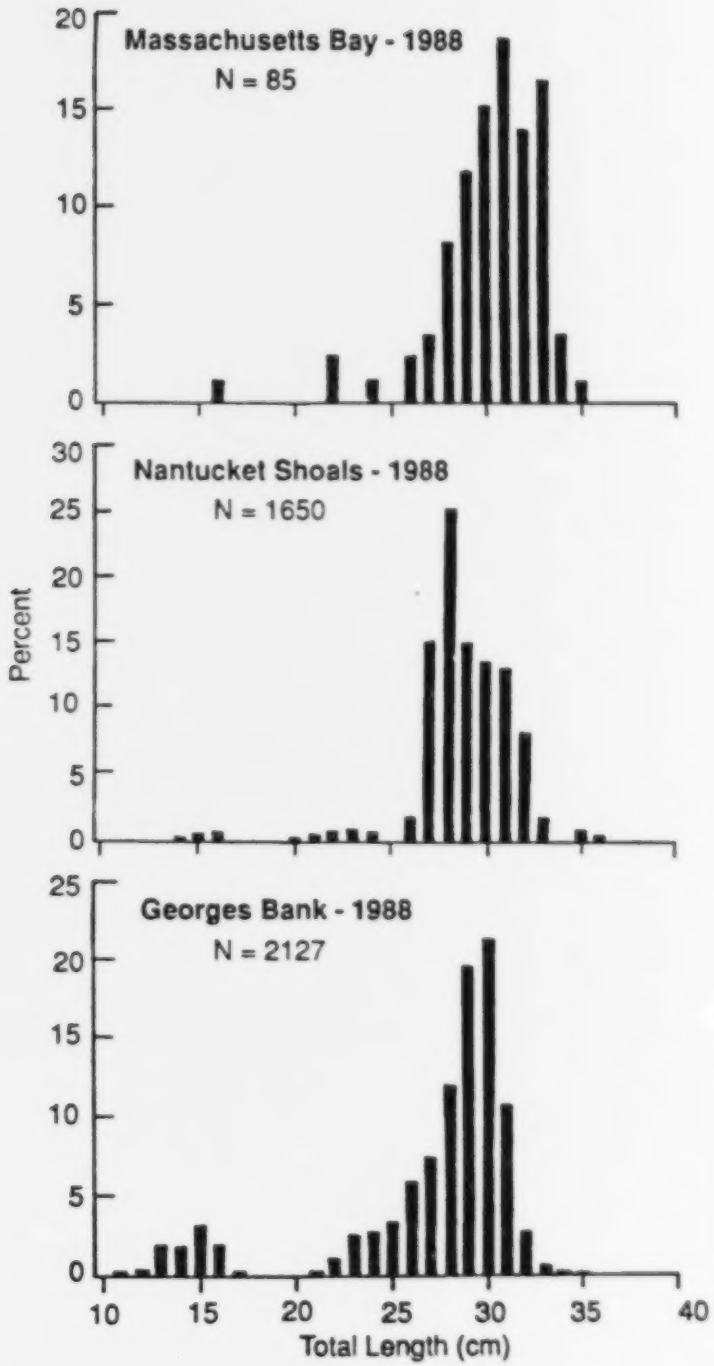

Figure 20. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals, and Georges Bank for 1988.

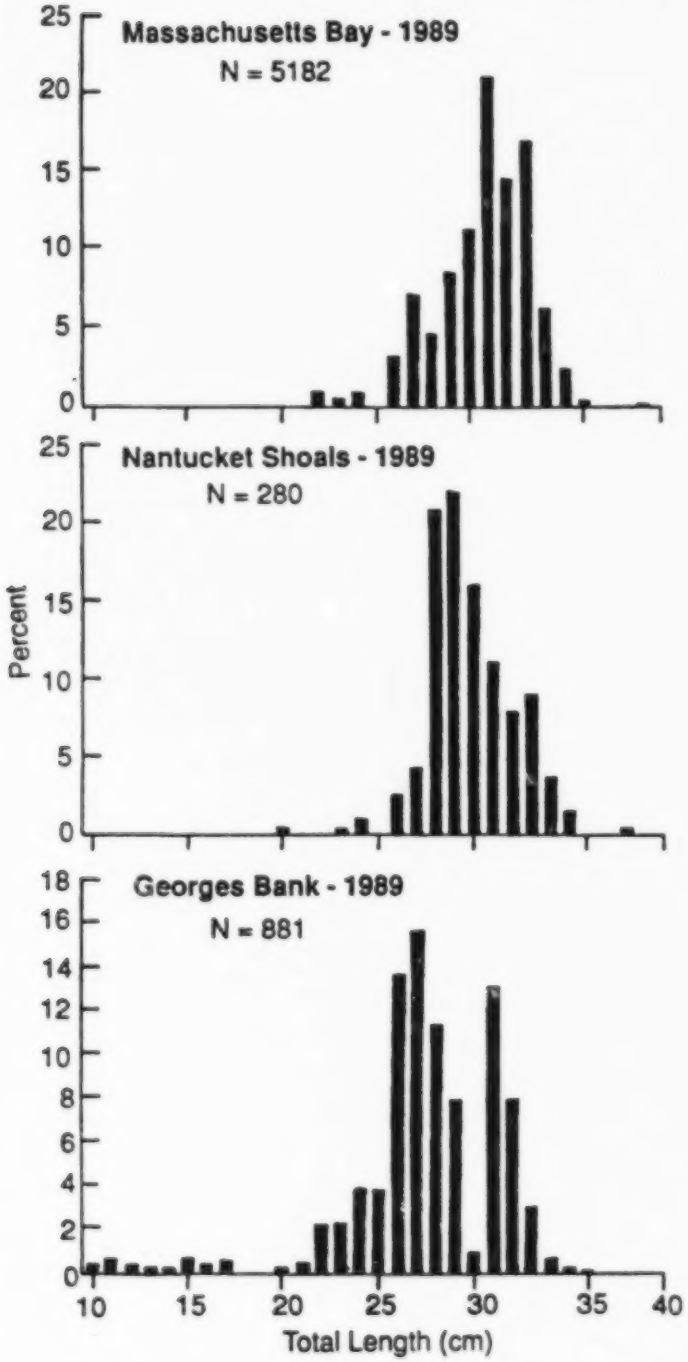

Figure 21. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals, Georges Bank for 1989.

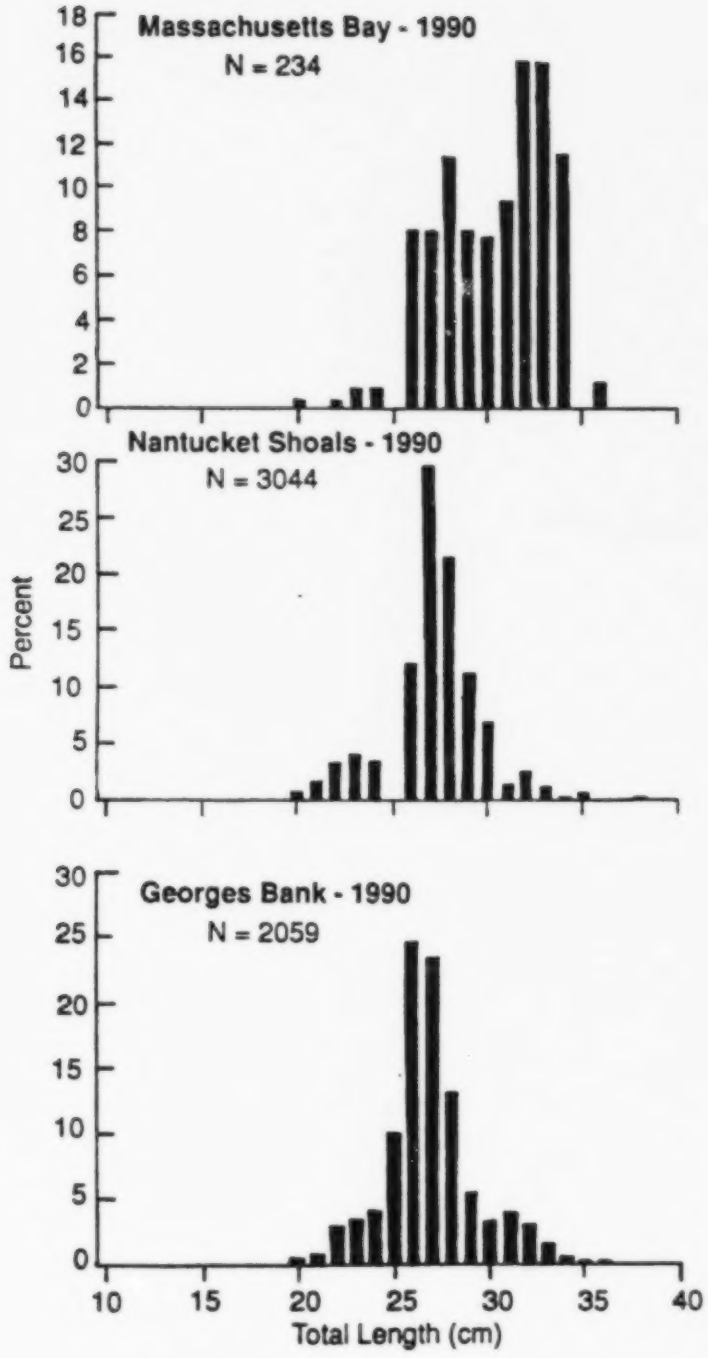

Figure 22. Length-frequency composition of samples collected from Massachusetts Bay, Nantucket Shoals, Georges Bank for 1990.

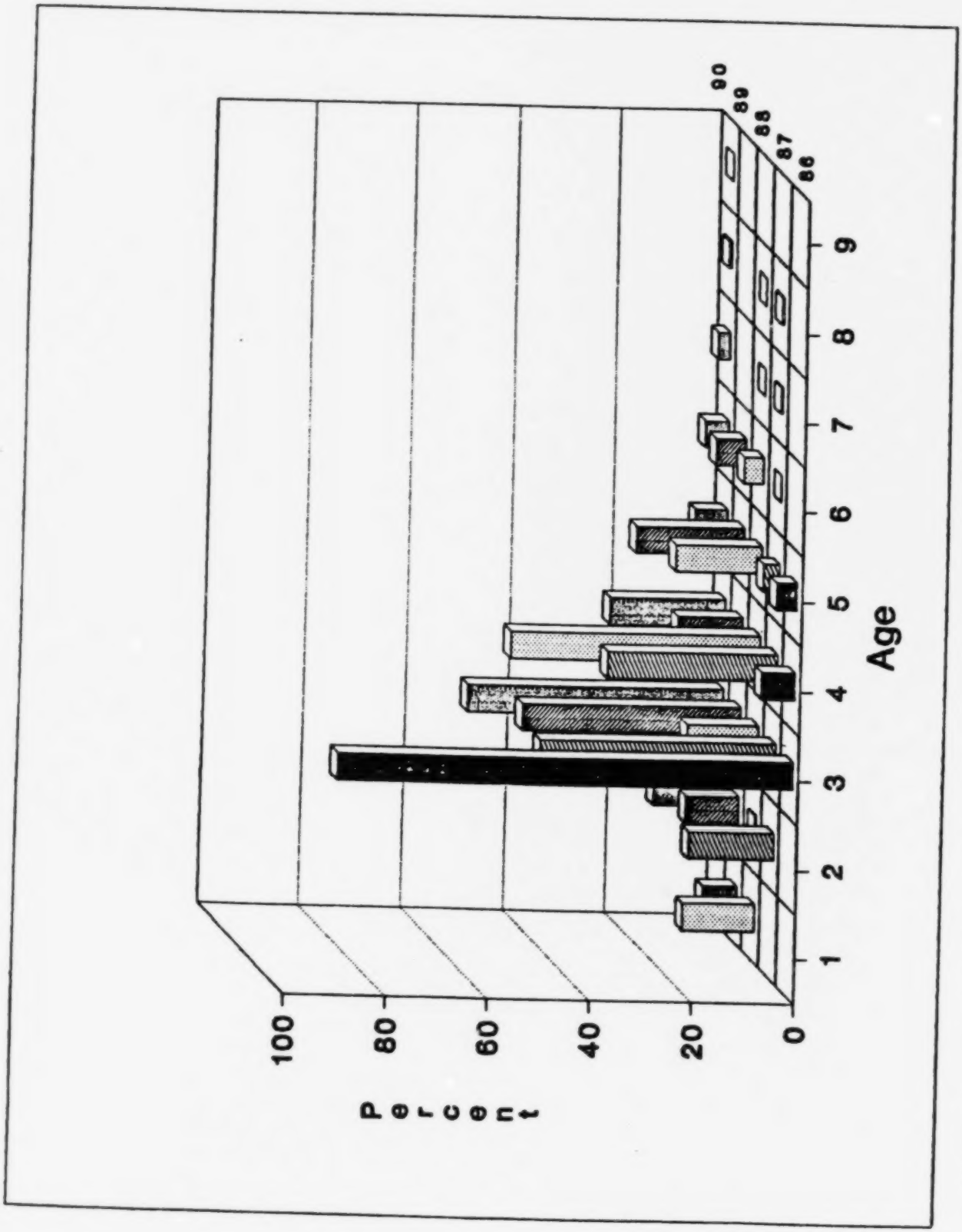

Figure 23. Age composition of herring collected on Georges Bank from 1986 to 1990.

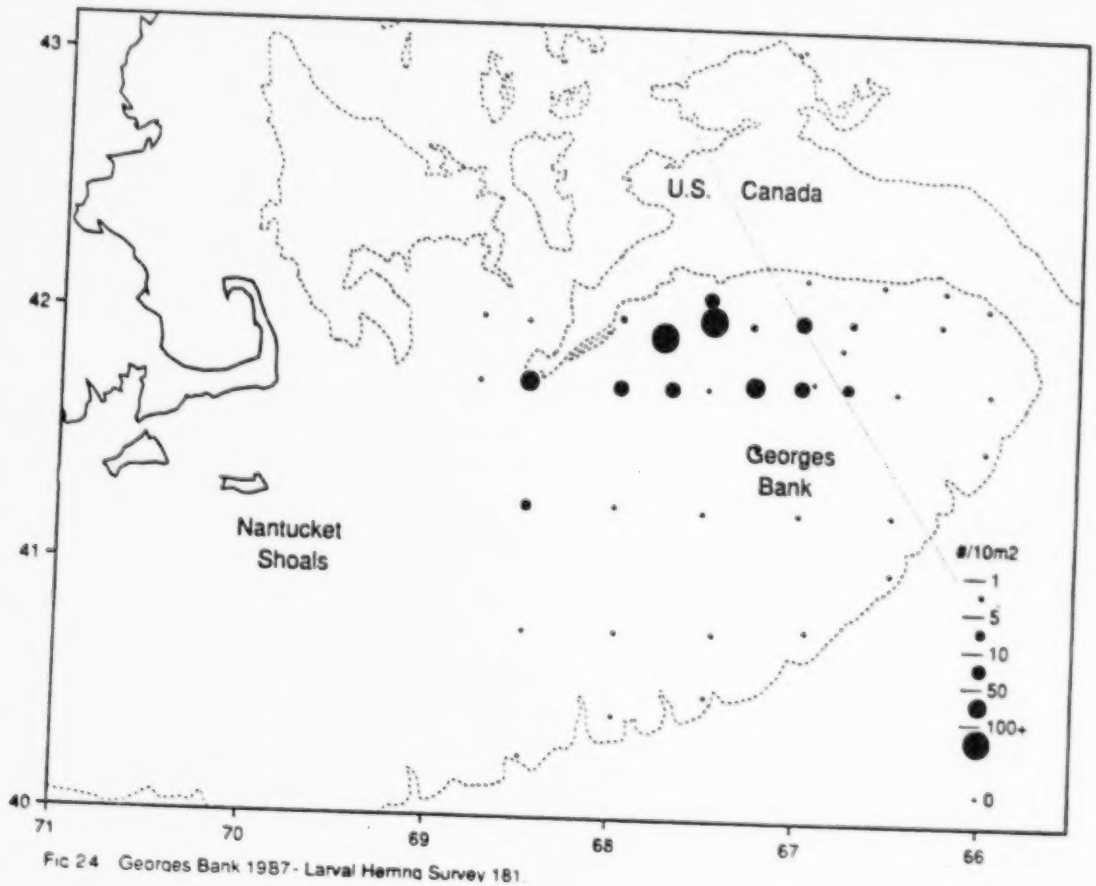

Fig 24 Georges Bank 1987 - Larval Herring Survey 181

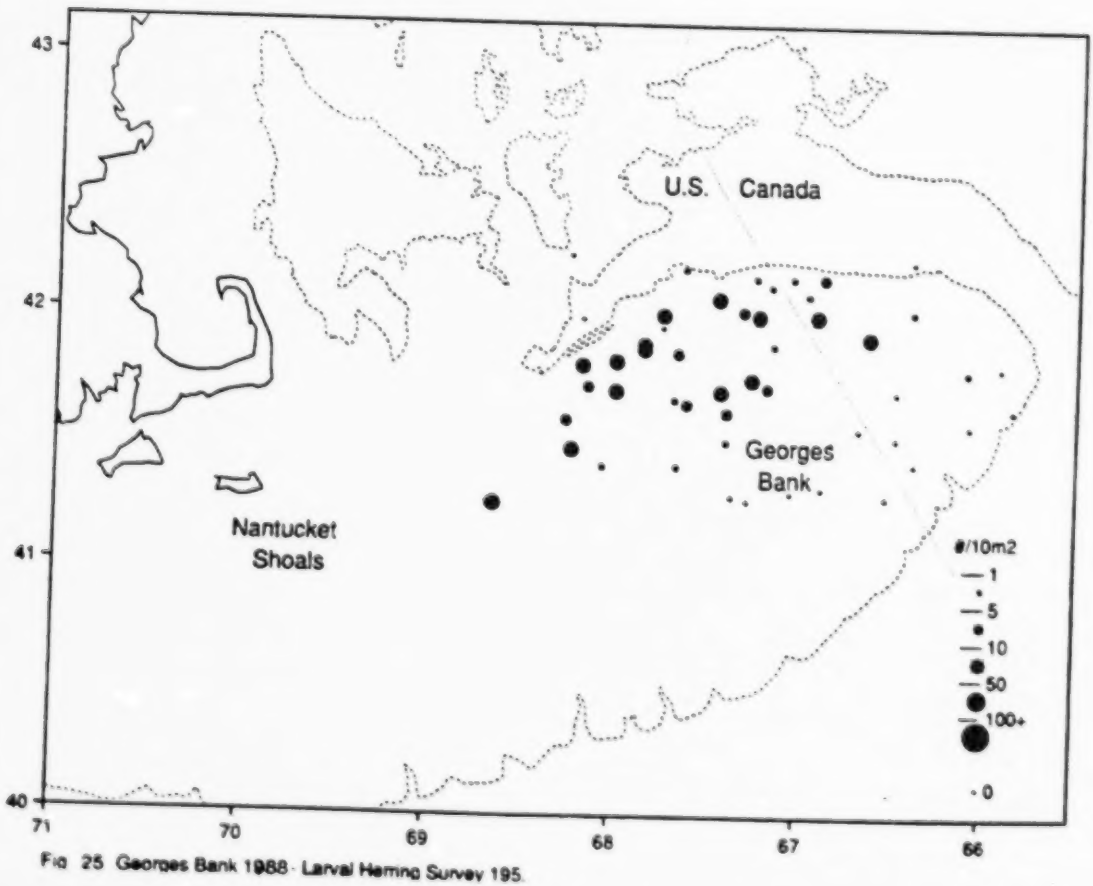

Fig 25 Georges Bank 1988 - Larval Herring Survey 195

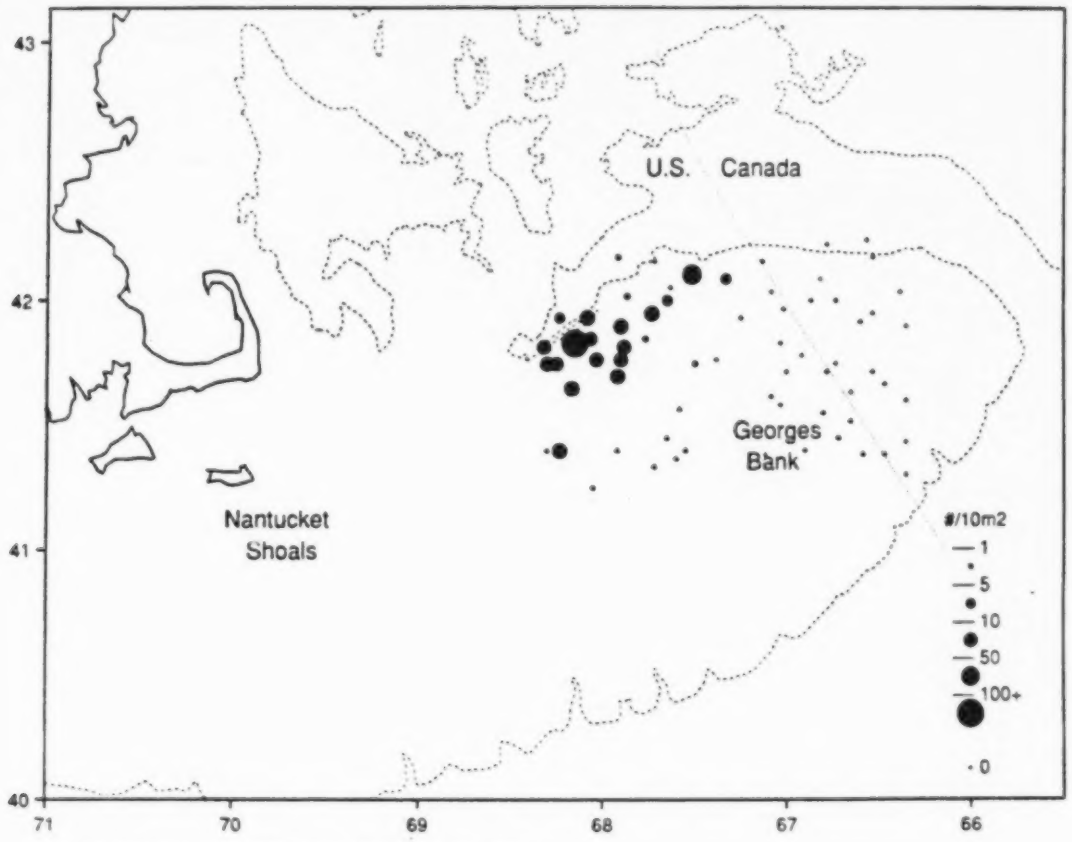

Fig. 26 Georges Bank 1989 - Larval Herring Survey 207.

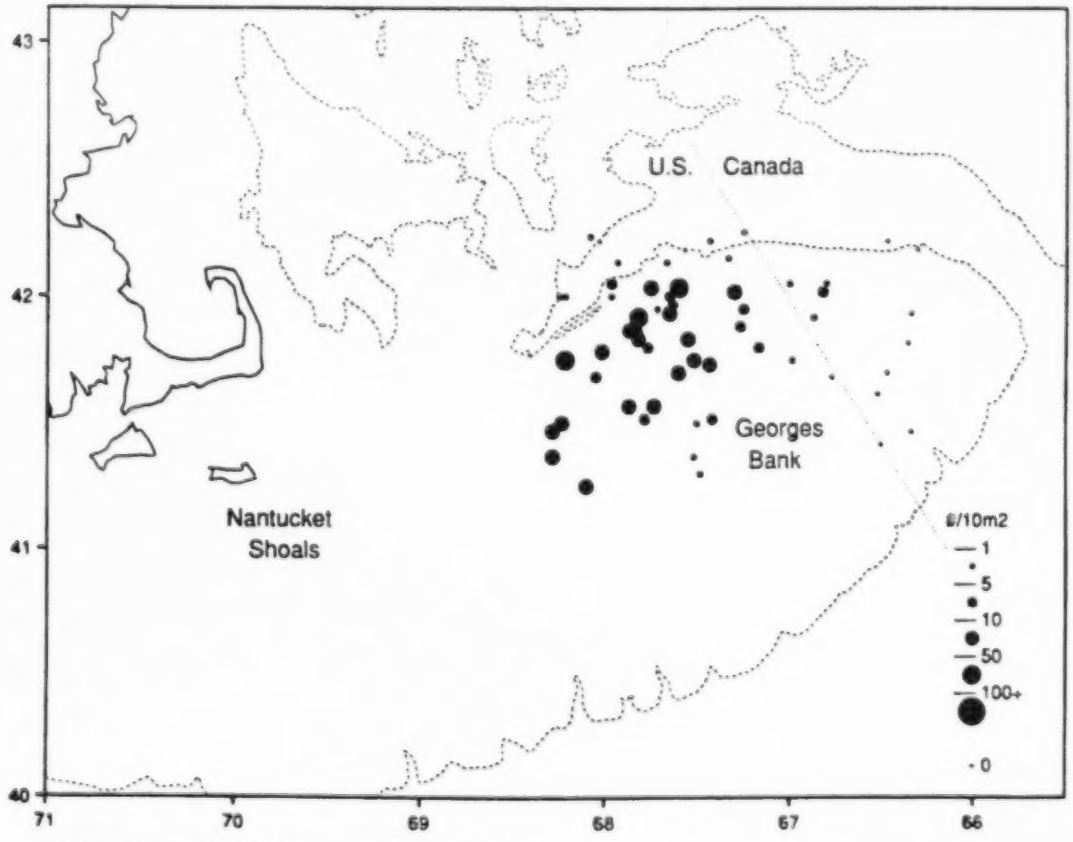

Fig 27 Georges Bank 1990 Larval Herring Survey 222.

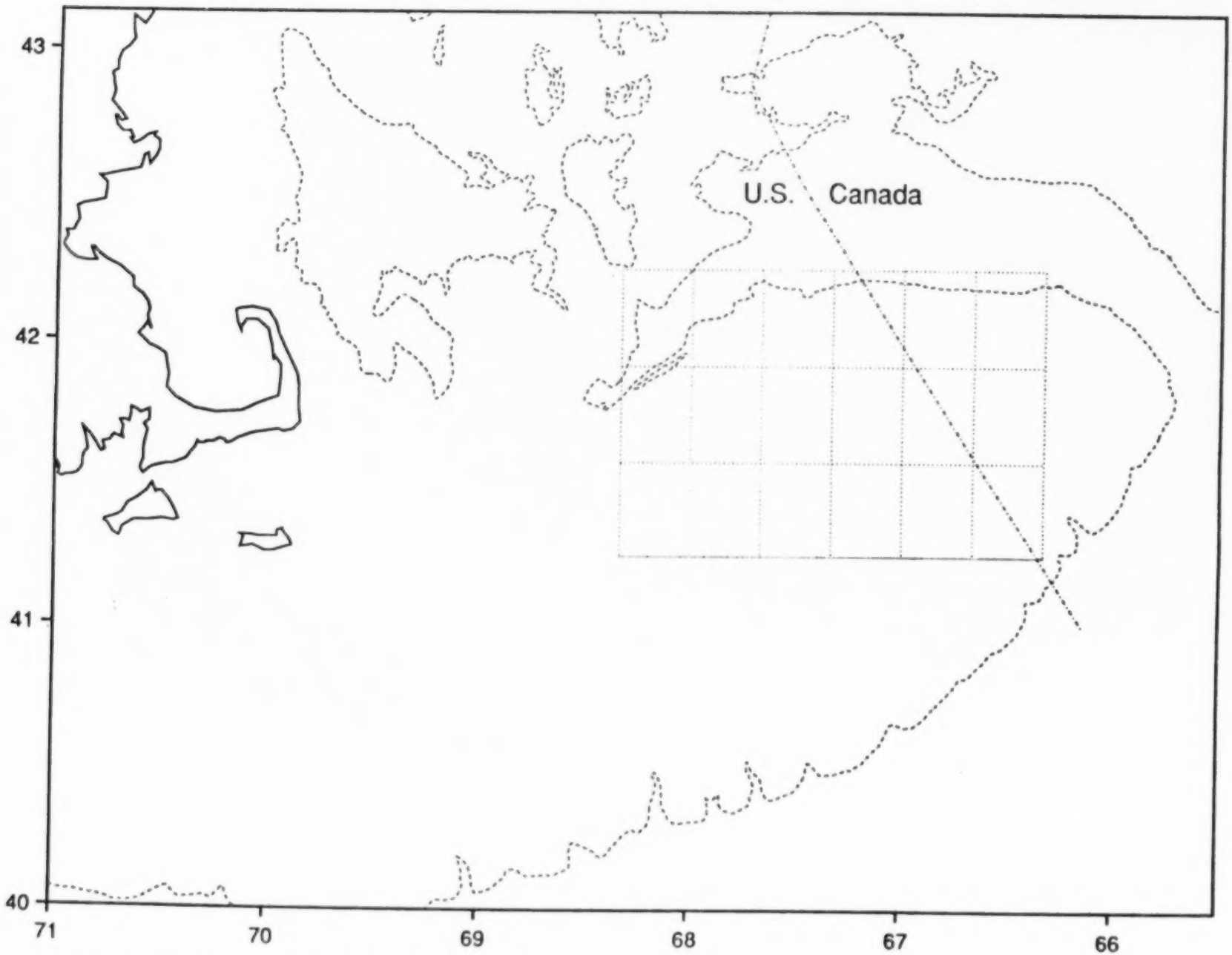

Figure 28. Larval grid system used by Canadian Surveys.

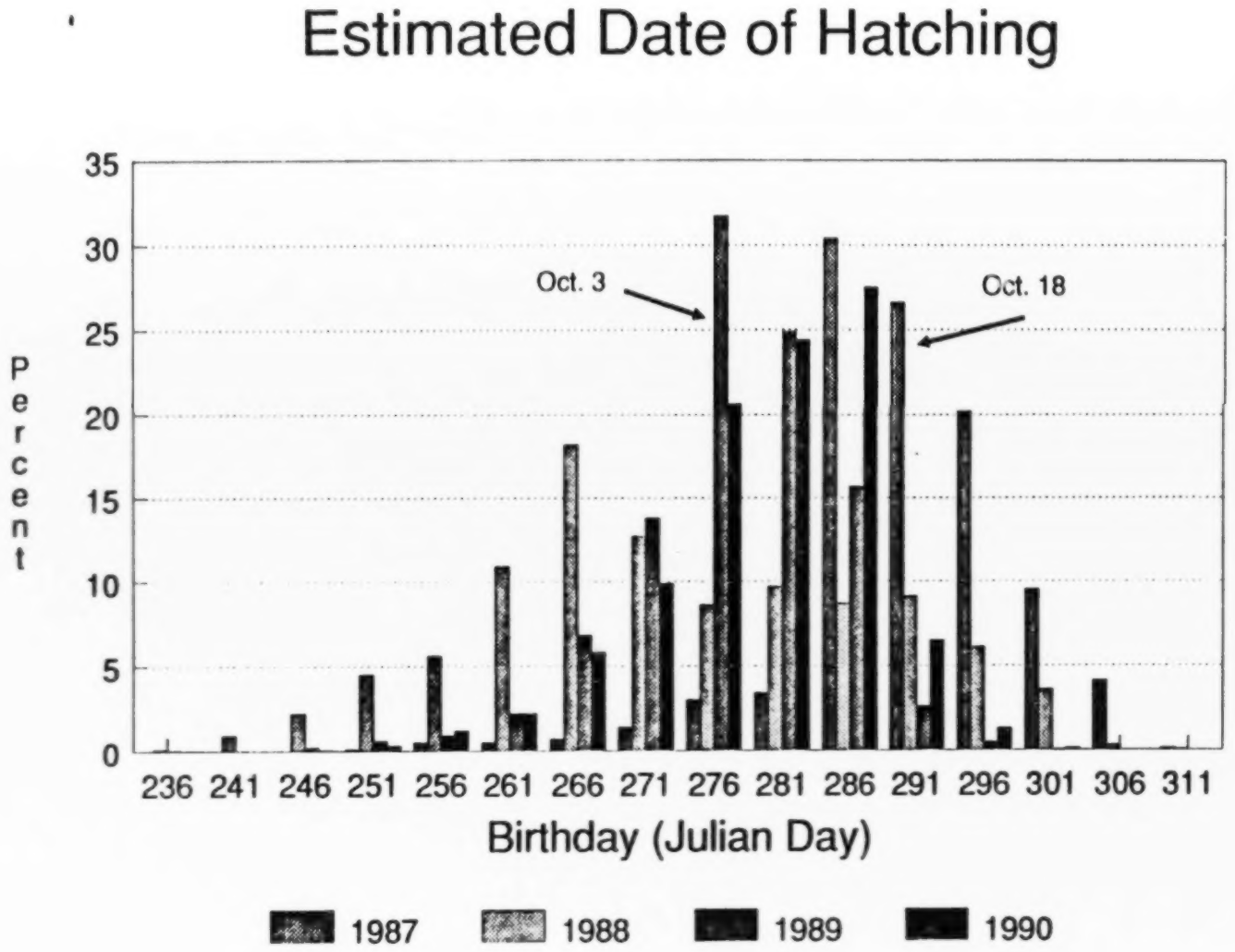

Figure 29. Estimated date (Julian day) of hatching for Georges Bank larvae.

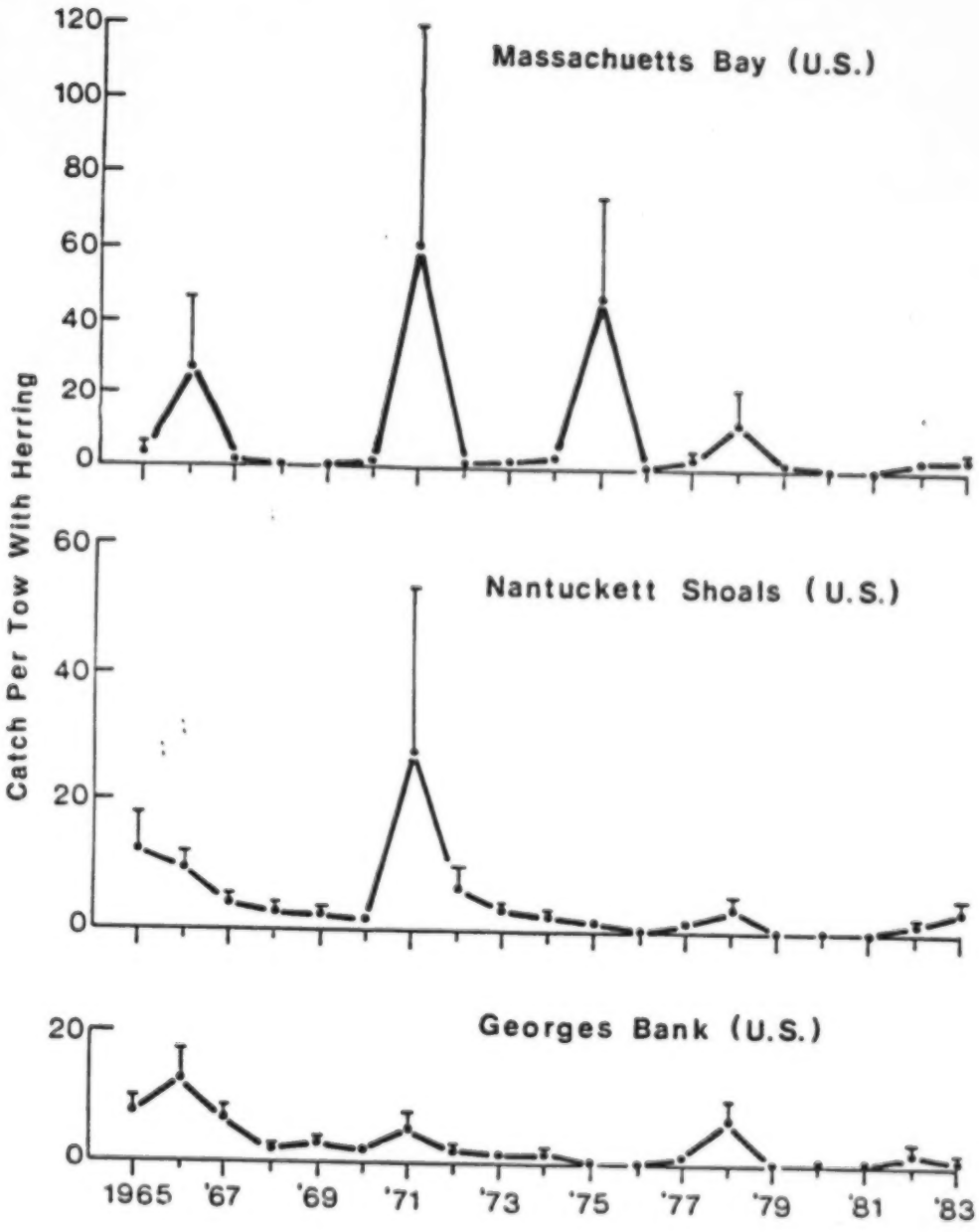

Figure 30. Summary of bottom trawl survey catch/tow with herring between 1965 and 1983. The bar represents 1 standard error.

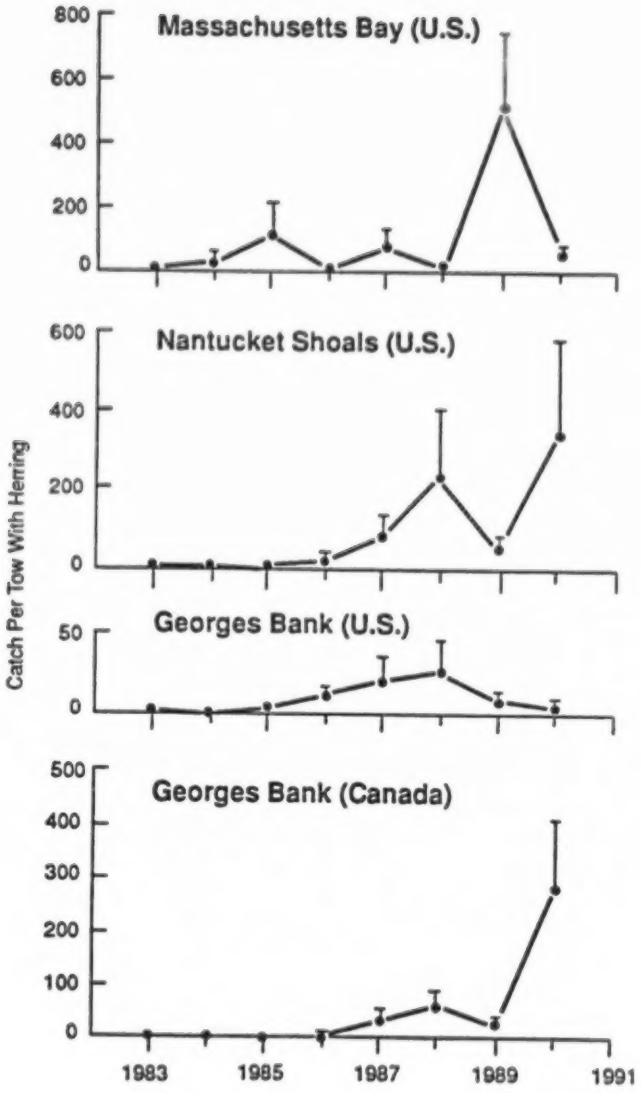

Figure 31. Summary of Canadian and US fall survey catch/tow with herring and their associated standard error between 1983 and 1990.

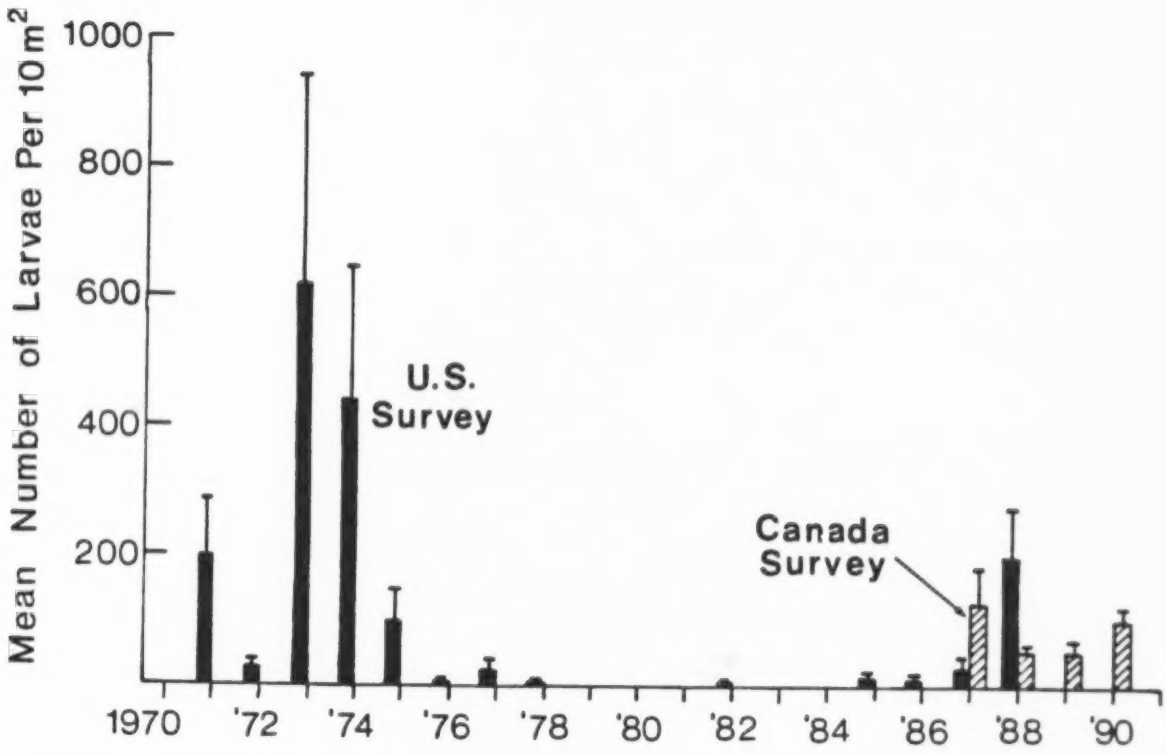

Figure 32. Summary of the estimated number of larvae per $10m^2$ and standard error by year for Canadian and US fall surveys.